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STATE-OF-THE-ART FINE CERAMICS TECHNOLOGY REPORTED

Design of High-Performance Ceramics

Tokyo SHINKINZOKU KOGYO in Japanese 87 pp 11-16

[Article by Hirokichi Tanaka, technical adviser, TDK Co., Ltd.]

[Excerpt] 2. Method for Providing Ceramics With Functions

Unless characteristics hidden in ceramics are cleverly drawn out and skillfully used, ceramics will remain just a simple pottery or crystal and will not become a special purpose material. Let us now take crystal as an example and consider what sort of methods there are for providing a crystal with interesting functions.

Crystal has the property of being beautiful and hard. Therefore, crystals have been conventionally used only for personal ornaments and as a material for seals utilizing this property. However, from the standpoint of materials science and solid state physics, there is a property called a piezoelectric effect in which the ends of a crystal electrify to plus and minus when a mechanical strain, such as a pressure or tension, is applied to the crystal piece. Moreover, there is a property called the reversed piezoelectric effect in which a crystal is mechanically strained when a certain voltage is applied to the crystal piece.

When voltage is applied to a crystal piece utilizing this reversed piezoelectric effect, the crystal expands and contracts and generates a vibration of several ten thousands of cycles per second due to this strain. This vibration frequency is determined by the size of the crystal piece and is an extremely stable and accurate vibration. This fixed vibration frequency has been applied to a timepiece, i.e., the crystal clock, and in addition, it has also been widely used for communication equipment parts, such as the frequency controller, filter, oscillator, etc.

Even for the same crystal, the added value will differ considerably according to whether it is made into a necklace and seal or whether it is made into communication equipment parts. Moreover, a good quality crystal is necessary for such a use. Therefore, a crystal that has been artificially synthesized is better than a natural crystal and, in the manufacture of synthetic quartz, Japan is the pioneer leading the world in its production volume.

As seen here, i.e., the process of cleverly drawing out the characteristics hidden in a certain material, artificially synthesizing a material with qualities corresponding to these characteristics and creating new values is the method adopted by fine ceramics. Later in this paper, some ways in which functions can be provided to ceramics will be given in more detail.

3. Application of Materials Science, Solid State Physics

The conventional utilization method involving ceramics had been one that was easily understandable to everyone as the relationship between the properties and applications seemed to be fairly straight forward. This included using ceramics with a small heat conductivity for insulators, those with a high melting point for fire-resistant materials and those with a high hardness for abrasives.

In recent years, however, providing functions has become extremely complicated and more and more complex with the application of materials science and solid state physics. If circumstances require it, the method of granting a certain material a characteristic which it does not have intrinsically, that is, the method of creating a characteristic, has also become possible. We will explain this method by taking the sintered material of barium titanate as the example. Barium titanate is originally an insulator of electricity. However, it is now used as a safe heating source by adding an extremely small amount of rare earth oxide to this barium titanate, burning it at a high temperature and changing it into a semiconductor, providing a function as a heating element. Furthermore, the nonlinearity of the electric conductivity can be used, providing the switchless switch function in which the current is naturally turned off when the temperature of the heating element becomes higher than a certain fixed temperature, with the current flowing naturally when the temperature of the heating element is lowered. Products employing the function include electronic jars, hair dryers, bedding dryers, etc.

The following is a simple explanation of this principle: First of all, approximately 0.1 to 1 percent of yttrium oxide (Y_2O_3) or lanthanum (La_2O_3) is added to the barium titanate powder, producing a sintered material. Barium titanate is a type of perovskite compound. It adopts a crystalline structure as shown in Figure 1--the A ion of the black-circled mark in the eight corners of the die-shaped structure is barium (Ba), titanium (Ti) enters in the small black circled mark at the center and the others are oxygen ions. When La_2O_3 is added, a part of the bivalent Ba^{+2} ion is substituted by the trivalent La^{+3} ion. Then a part of the quadrivalent Ti^{+4} ion becomes the trivalent Ti^{+3} ion and the electrical neutrality of the entire ($Ti^{+4} + e \rightarrow Ti^{+3}$) system is maintained. This means that the electron (e), seized by this Ti ion, passes a current and becomes a semiconductor.

The electrical resistance of the barium titanate sintered material which has become this semiconductor is shown in Figure 2. In the case of the sample referred to as A 3, it passes the current well at a resistance of about 10Ω and up to a temperature of approximately 100°C, but when the temperature becomes 150°C, the resistance increases to about 10,000Ω and the current does not flow. When the temperature decreases, the resistance returns to its former value and the current starts to flow again. A safe heating element

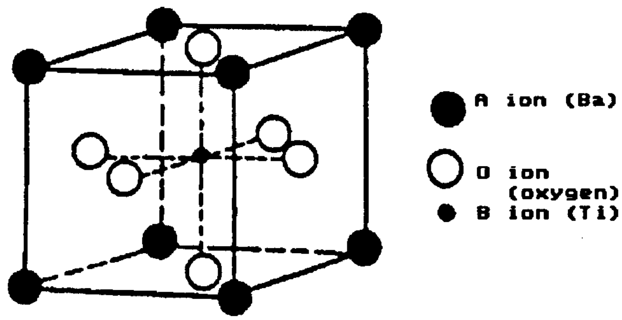


Figure 1. Perovskite Type Structure (Case of cubic structure)

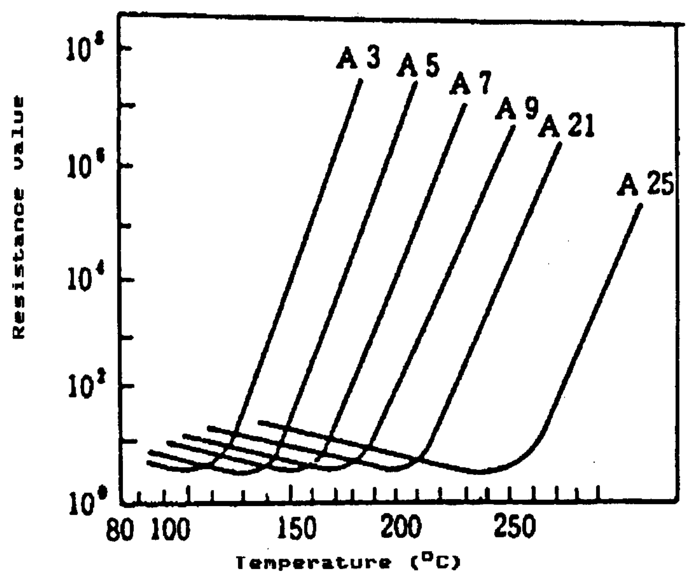


Figure 2. Relationship Between the Electrical Resistance Value and Temperature of Semiconductive Barium Titanate Element ($BaTiO_3$-La System)

When the temperature of the semiconductor element becomes high, the electric resistance of the element suddenly becomes high and it changes into an insulator.

with the switchless switch function is made in such a manner. It is possible to change the operating temperature of the switch according to the type and amount of additives used, such as from A 3 to A 25.

It is necessary to cleverly utilize the theory of semiconducting by valence control and modern materials science and solid state physics effects, such as the nonlinearity characteristic of electric resistance, etc., to provide such a function to electric insulator barium titanate.

4. Application of Conversion Characteristics of Energy Forms

In rearranging the characteristics and functions involving fine ceramics which we have explained up to now, we find that the crystal (SiO_2) used as an oscillator in a timepiece, etc., has been utilized by converting the electrical energy, as the input, into a mechanical energy called vibration.

In addition, the zirconate titanate sintered material (solid solution of $PbZrO_3$ and $PbTiO_3$), used in the automatic ignition device for gases, converts the mechanical energy of vibration into high voltage electrical energy, igniting gases through the spark discharge. Moreover, the γ-hematite (γ-Fe_2O_3) used in an audio tape stores the sound changed into an electrical signal as a magnetic signal and it invertly changes the magnetic signal into an electrical signal and the electrical signal into a sound when so desired. All of these are said to be the utilization of the conversion function involving energy forms.

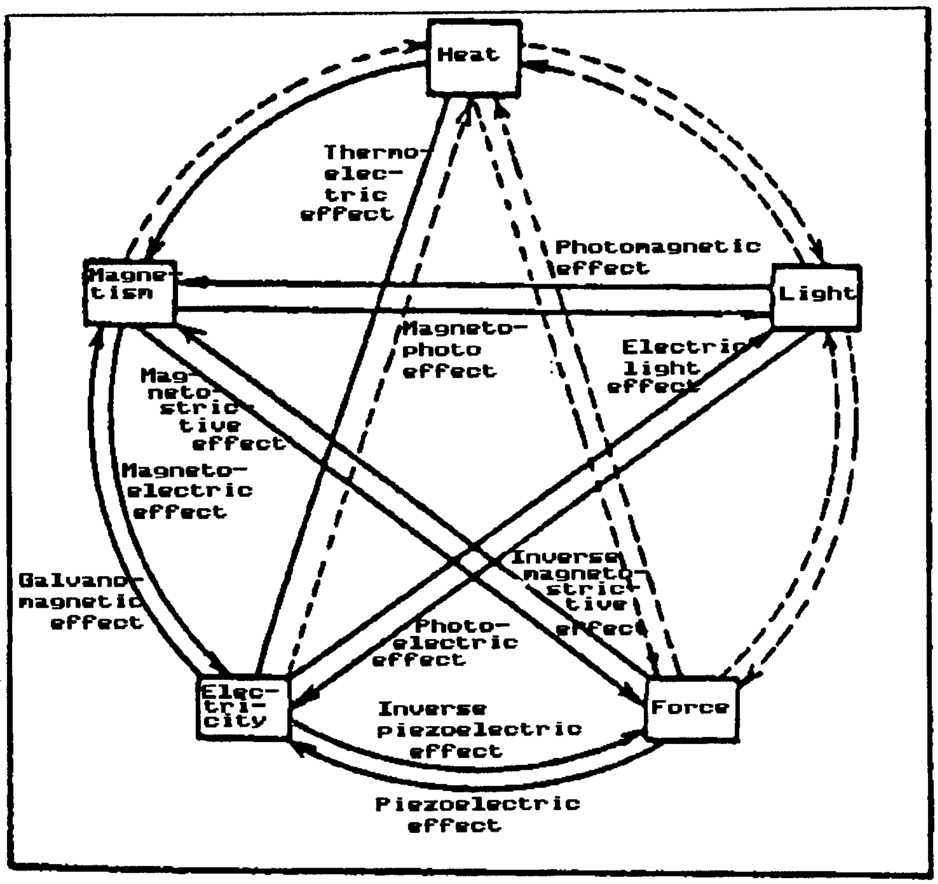


Figure 3. Relationships of Various Physical Effects
For example, the piezoelectric effect is a phenomenon in which a potential difference is generated on the surface of the material when an external pressure (pressure or tension) is applied to a certain type of material. The mechanical energy can be changed into electrical energy by this effect.

All these phenomena are things known in physics as the "such and such effects" and the diagram in which these are arranged simply is shown in Figure 3. These effects are further subdivided, e.g., the electric light conversion effects include the Pockels effect, Kerr effect, electroluminescence effect, etc., with all utilized for various purposes, however, they will be omitted here this time.

It does not mean that this conversion function on energy forms does not exist on metals and plastics, however, examples of these are few and their actions are not as effective as in ceramics. Therefore, ceramics is considered to be a major use for this interesting property.

Table 1 has categorized the various uses for energies when an input is converted into different energies. It becomes possible to develop various sensors by converting the energy of heat, light, and chemistry (for example, micro gas components in air, etc.) into an electrical energy, and then measuring it.

5. Application of Crystalline Chemistry

Crystalline chemistry is a branch of learning which studies what kind of array the atoms and ions composing the material adopt (atomic array) and by what kind of strength the atoms and ions are bonded (bond mode).

Studies have recently been conducted on this crystalline chemistry in the relation to the mechanical, optical, and electromagnetic properties and, by absorbing and applying these results, the development of ceramics with new properties has become possible.

For example, if a "center of symmetry" is not found in a crystalline structure when the atomic array is checked by X-ray, it may be that this measurement will be attempted since it has been proven effective for the prediction of properties, and piezoelectric effect. Moreover, since materials with similar atomic arrays and bond forms are mutually susceptible to forming a solid solution, they are frequently utilized for the improvement of properties.

For example, since sintered barium titanate has an extremely large dielectric constant, it is widely used as a condenser. As shown by A in Figure 4, however, the dielectric constant of barium titanate suddenly drops independently when the temperature decreases to less than 0°C, and therefore, problems are encountered in cold zones. Therefore, as shown in Figure 4, a condenser in which the dielectric constant does not change much even when the temperature decreases to less than 0°C has been made by utilizing crystal chemical knowledge and a solid solution of another material with an atomic array and bond mode similar to those of barium titanate (compound having the perovskite type structure shown in Figure 1).

6. Application of Intergranular Sintered Materials

Ceramics can be largely classified into three types--the single crystal type like quartz, the polycrystal type in which crystal powders have been baked like pottery (also called sintered material) and noncrystalline material type

Table 1. Inorganic System Special Purpose Materials (Energy conversion)

Output \ Input	Mechanical energy	Heat	Light	Radiation	Sound	Chemistry	Electricity	Magnetism
Mechanical energy	· Foaming material · Brake material						· Piezoelectric element	· Magneto-strictive element
Heat		· Heat insulating material · Conducting material · Regenerating material	· Selective absorption film			· Heating element	· Heating element	
Light		· Infrared radiating material	· Fluorescent substance (laser, fluorescent glass) · Chemical fiber · Polarizing element · Transparent material · Photochronic	· Dosimeter · Scintillator	· Acousto-optic element	· Chemi-luminescence substance	· Infrared radiating material · Fluorescence substance · Semiconductor laser	· Magneto-optical element
Radiation				· Reflector · Absorption material · Moderator				
Sound					· Sound absorbing material			
Chemistry			· Photosensitive glass · Photochemical effect			· Catalyst		
Electricity	· Piezoelectric element · Strain resisting element	· Solid electrolyte · Sensor · Pyroelectric element	· Electrooptical effect · Photoconductivity · Sensor · Solar cell	· Sensor	· Sensor	· Sensor · Solid electrolyte	· Delay element · Heat-insulating material · Varistor · Condensor · Magnetic valve · Filter · Superconductivity	· Sensor
Magnetism	· Magnetostrictive element	· Temperature Ferrite				· Sensor		· Magnetic shield

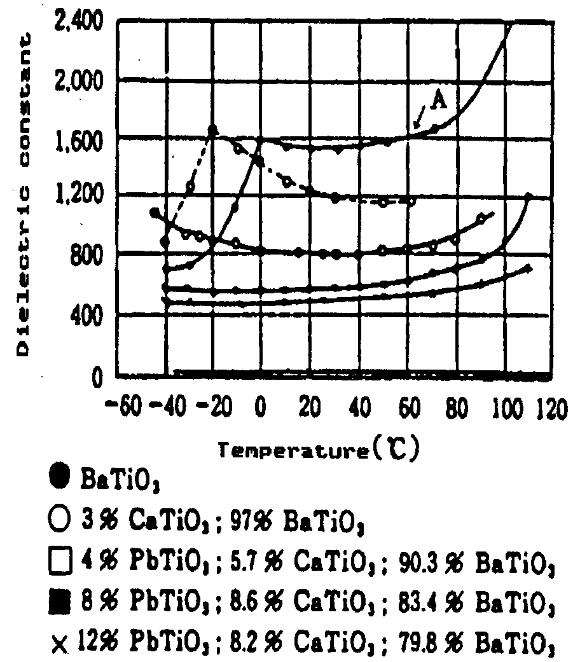


Figure 4. Relationship Between the Dielectric Constant and Temperature of Barium Titanate System Sintered Material
The temperature characteristics of the dielectric constant can be changed by making a solid solution.

represented by glass (also called amorphous material). Of these three types, the ceramics most widely used for industrial purposes is the sintered material called pottery.

When observing a sintered material with a microscope, we find that it has a complicated fine structure where boundary layers (intergranulars), bubbles and inclusions are geometrically distributed among particles (fine crystals) and, in this aspect, it greatly differs from the single crystal and glass types which are entirely homogeneous in structure. When considered from the viewpoint of crystalline chemistry, previously explained, it can be assumed that the properties of a sintered material indicate the set properties of the crystals composing the sintered material. However, nature is complicated, and occasionally a sintered material shows a special property that cannot be absolutely determined from the properties possessed by a single crystal.

It has come to be understood that such a property difference has resulted from the fine structure and, especially, from the intergranular layer of the sintered material. Therefore, a material with a special property that had not previously been available in a single crystal has been developed recently by controlling the intergranular layer.

For example, take the varistor of zinc oxide (ZnO) in which impurities have been segregated in the intergranular layer. When very small amounts of

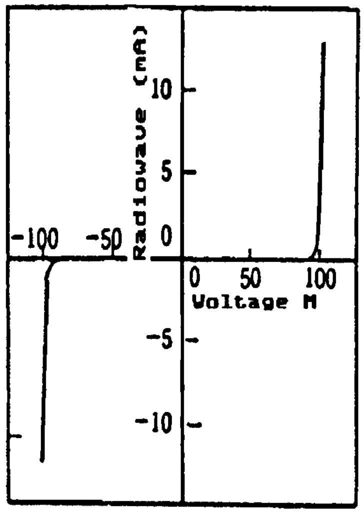


Figure 5. Relationship Between the Voltage and Current of Zinc Oxide Varistor (ZnO:Bi)
The current suddenly starts to flow when a certain voltage is applied. This characteristic has been utilized in the voltage stabilizer of a TV high-voltage circuit, abnormal voltage absorber of a thyristor, lightning arrester, etc.

bismuth oxide (Bi_2O_3) and rare earth oxide are added to the zinc oxide powders and sintered, the Bi_2O_3, etc., which are not soluble in ZnO, segregate in the intergranular layer. The relationship between the voltage and current of this sintered material, as shown in Figure 5, indicates an interesting property in which current does not flow even when the voltage is initially raised, but the current suddenly starts to flow when a certain voltage (e.g., a voltage close to 100 V) is applied. The zinc oxide, itself, is an n type semiconductor and does not indicate such a property.

Such a keen varistor is widely used as an abnormal voltage absorber, lightning arrester, and a voltage stabilizer for high-voltage circuits, etc. Although various views have been proposed as to why the intergranular layer exhibits this phenomenon, including the space-charge limited current model, n-p-n type junction model, tunnel effect, Schottky barrier model, etc., the true reason is not yet clear. There are many unknown facts and it is a field in which great possibilities exist for the discovery of further interesting functions in future research.

7. Application of Shape and Form Changes

The properties of ceramics of the same material will change when their shapes and forms are changed, such as making them into a thin film shape, a fibrous form or a porous form, and it becomes possible to draw out the characteristics applicable to the purposes. This is shown in Table 2. Let us now explain by taking aluminum oxide (Al_2O_3) as an example. The product obtained by performing anodic oxidation on the surface of an aluminum receptacle and forming a thin aluminum oxide film on its surface is the so-called "alumite"

Table 2. Inorganic System Special Purpose Materials (Function improvement by form)

Form / Function	Thin filming	Miniaturizing 1)	Fibrosis	Porosis	Compounding	Imperforation	Others
Optical	.Selective absorbing film .Solar cell	.Glass beads	.Optical fiber		.Surface deposition	.Transmitting material .Laser host	
Electro magnetic	.Transparent electrode .Sensor .Magnetic bubble	.Magnetic powder		.Sensor	.BN condenser .Varistor	.Thermoelectron radiation material .Glaze .Single crytal and amorphous substance 2)	.Condenser
Acoustic	.Ultrasonic element		.Sound absorbing material	.Sound absorbing material	.Noise insulating and sound absorbing material	.Ultrasonic element	
Thermal			.Heat-insulating material .Heat pipe	.Heat-insulating material .Honeycomb heating element	.Heat-insulating material .Ceramic coating		
Separation and absorption	.Filter material		.Filter material	.Filter material			
Mechanical	.Surface hardening material (PVDF)	.High intensity material .Lubricant	.Reinforcement		.FRC .Cermet .Wear resisting material	.Wear resisting material	.Adhesive .Lubricant
Transport carrier					.Microcapsule (thermal energy storing material)		.Hazardous material solidification
Chemical			.Catalyst	.Catalyst .Ion exchange material .Electrolytic film		.Glaze	.Solid electrolyte
Biological				.Oxygen fixation .Artificial bone .Artificial tooth		.Artificial bone	.Adhesive (piezoelectric utilization)

1) Also includes pulverizing

2) Magnetic valve, piezoelectric material, semiconductor, etc.

which withstands chemical corrosion well. Moreover, the aluminum oxide fiber excels as the reinforcing material for a heat-resisting composite material. The material made by completely melting the aluminum oxide powders using an oxygen-hydrogen blaze and forming them into a single crystal is the artificial ruby and sapphire, which are widely used for precious stones and laser materials. This method of changing the shape and form is also one used to draw out the characteristics.

8. Application of Mechanical Properties

The properties mentioned above mainly involve the utilization of electromagnetic characteristics, however, there is another important characteristic for ceramics. This characteristic is the property of being hard, chemical resistant, possessing an extremely high strength and withstanding temperature well.

Applications to equipment and apparatus demanding heat-resisting properties, corrosion resistance, and wear resistance as seen in Table 3 have recently been promoted utilizing these characteristics. This is because technology has progressed involving sintering materials, such as carbon silicide (Sic) and silicon nitride (Si_3N_4), with a high heat conductivity up to a high strength under a low coefficient of thermal expansion, and methods promoting the tenacity of ceramic sintered materials, such as partially stabilized zirconia (ZrO_2), etc. are also making progress.

Table 3. Examples of Uses of Si_3N_4 and SiC Ceramics

Used areas	Uses
(1) Static heat-resistant materials	Heat-resistant wall, heat exchange wall, high-temperature fluid passage, valve, insulator, rail.
(2) Static anticorrosion materials	Lining, passage, nozzle, valve, pump, and crucible for the chemical and metal industries.
(3) Dynamic heat-resistant materials	Small turbo fan for high temperature fluid, pump, high temperature body conveyance equipment parts, roller, bearing, gear, chain.
(4) Wear resistant materials	Slurry passage, pump, valve, parts for machines and tools, parts for precision machines, guide for mechanical seal, line, and tape.

Uses in the table are those which can make the best use of advantages, such as the high modulus of elasticity, low thermal expansion and wear resistance of ceramics, and they will be used commercially in the near future. Their application to a turbine blade, etc., is a challenging task for the future.

When using ceramics as mechanical parts subject to stress, the most significant problem involves their sudden breakage with no prior warning, thereby indicating unreliability.

However, the understanding of the breaking mechanism of ceramics has progressed in recent years, the inspection method of microscopic flaws which can become the cause of breakage and the prediction method for longevity have also progressed, and a guarantee of life expectancy has also become possible to a certain degree. Research is not yet sufficient in this field, but several countries are exerting a great deal of effort so that ceramics can be used without anxiety, although they may be considered "fragile" under the guaranteed conditions and within the guaranteed time. Presently, an automobile turbo charger capable of rotating at more than 100,000 rpm at high temperature has also begun being put to practical use.

9. Conclusion

Fine ceramics will be one of the large pillars to support renovation techniques of the future and it is considered that the following are necessary for developing fine ceramics:

(1) Necessity to develop new special function materials.

(2) Understanding of new phenomena based on materials science and solid state physics, and development of seeds by new materials search, etc.

(3) Linking of needs with these seeds and materials technology progress in order for this to materialize.

Furthermore, since fine ceramics is not only a simple inorganic chemical industry but also a skill and engineering project involving various territorial boundaries, including materials science, solid state physics, mechanical engineering, and electrical engineering, international cooperation among researchers in these specialties is necessary for this development

Survey of Trends

Tokyo SHINKINZOKU KOGYO in Japanese Jan 87 pp 17-26

[Article by Shogo Shimizu of Toshiba Corp.]

[Excerpt] 1. Introduction

Great expectations have been placed in structural fine ceramics, especially in Japan, as a new material capable of providing a great impact on resources and energy. Its development was, therefore, accelerated, and information on the results of its development and merchandizing even seemed excessive at one time. However, it reached a peak with the development of the ceramic turbo rotor for automobiles, and is now observed as having slackened.

On the other hand, however, the participation of enterprises in this field is increasing, as usual, and it has also been observed that the period has begun in which various ceramics will be preferred for simple applications, with some gradually entering the market in the future.

This text presents a survey on the development trend of structural fine ceramics according to research data prepared by the Material Development Special Committee of the Japan Machinery Federation.

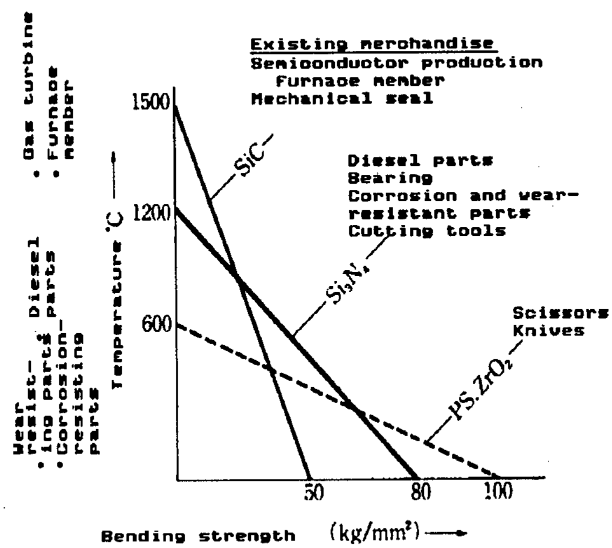
2. Types of Special Features of Structural Fine Ceramics

Those on which development is focused are the silicon nitride, silicon carbide, and partial stabilized zirconia systems. Particularly, the mechanical strength of these structural fine ceramics is ever-progressing and the representative examples are shown in Table 1. The concept drawing (Figure 1) indicates the proper use of these three types of ceramics by the used temperature and bending strength, and it agrees well with present applications. In other words, the proper use of structural fine ceramics includes silicon carbide being used for high temperatures of up to 1,500°C, regardless of whether the bending strength is less than 50 kgf/mm², partial stabilized zirconia used for bending strengths of up to 100 kgf/mm² regardless of whether they are less than 600°C, and silicon nitride used as an intermediate between the above-mentioned two. Those that have already become commercialized are indicated in the table.

Table 1. Types and Special Features of Structural Fine Ceramics (Atmospheric sintered products)

	Si_3N_4	SiC	ZrO_2	Notes
Bending strength (kg/mm²) Ordinary temperature	90~100	50~70	90~100	See attached figure of Table 1
Bending strength (kg/mm²) 1000°C	80~90*2	50~80*4	50~60	
Thermal shock temperature difference (°C)	700*1	350~550	350	
Hardness (Hv)	1500	2900	1500	
Tenacity K_{IC} (MPa·m$^{3/2}$)	5	4	10^{5}	More than 30 for metals
Sliding abrasion (mm³/kg·mm)	3.0	1.3*3	—	
Specific gravity (g/cc)	3.2	3.2	6.0	
Heat conduction (Cal/cm·sec·°C)	0.06	0.2	0.005*6	Al 0.5
Resistability (Ordinary temperature) (Ω cm)	$>10^{14}$	$<10^{3}$	—	
Thermal expansion (10^{-6}/°C)	3	4	10	18-8 Stainless 17
Special features	*1. Strong against thermal shock *2. For high strength up to 1,000°C	*3. Wear resistance great *4. For medium strength up to 1,600°C	*5. High tenacity *6. High heat-insulating property	
Areas of main use	. High strength parts for diesel	. Medium strength parts for gas turbine	. Cutting tools · Diesel heat-insulating parts	

Attached figure of Table 1. Comparison of Temperature Reliability of Bending Strength



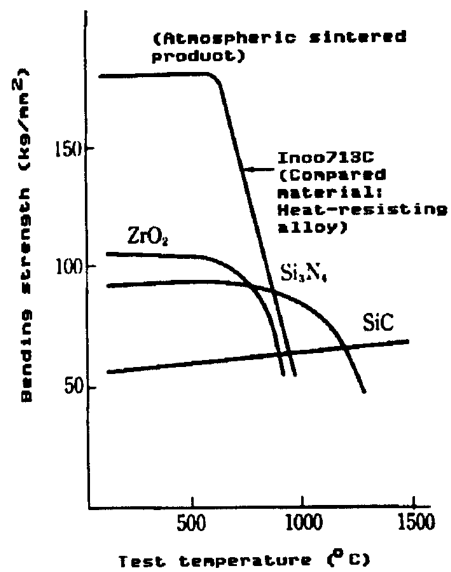


Figure 1. Concept Diagram of Proper Use of Structural Ceramics

3. Development Trends

1) Overseas trends

The scale of the national project for the development of structural fine ceramics was approximately ¥100 million for the United States for the period 1970 to 1985, and this was 10 times that of Europe (1970 to 1985) and Japan (1981 to 1990) each with the scales of approximately ¥10 million.

In contrast to the development goals for the national projects of the United States and Europe which have been directed toward the realization of the high performance of equipment and apparatus for military and space use, especially involving the gas turbine, the development goal for Japan started from energy- and resource-saving measures, and with the basic technical development of materials as its distinctive feature. Moreover, in contrast to the national projects in the United States and Europe being initiated by the government, developments made by the enterprises themselves are active in Japan and, among these developments made, the interest is high regarding those made for the people's livelihood, especially diesel parts.

However, the objective materials are common to all three, the United States, Europe, and Japan, with silicon nitride, silicon carbide, and partially stabilized zirconia as the main materials.

Since the United States has a large-scale national project, many universities and researchers participate in the R&D, basic scientific knowledge is complete and positive achievements involving demonstration tests conducted within the ultimate limits in the military and space fields are abundant. Basic research on the microstructure analysis and its control is actively being conducted in West Germany for Europe, whereas production technical knowledge is progressing in Japan.

There are many technical factors requiring development in structural ceramics, and since a considerable cost is required over a long period, the burden will be too great for independent development by a company as the market expansion will not occur as rapidly. Therefore, cooperation among enterprises becomes an important strategy. There are many examples of lenient tieups, such as joint research and license exchange when the cooperator is a European enterprise, however, the trend is becoming strong toward rather strict cooperation, even demanding the establishment of a joint corporation when the cooperator is an American enterprise. The tieup condition in Japan is active and an investigation on this is shown in Table 2.

Table 2. Examples of Domestic Tieups Involving Fine Ceramics

Name of enterprise	Type of business	Name of tieup partner	Partner's type of business	Contents of tieup
Kyocera Corp.	Ceramics	Nippon Piston Ring Co., Ltd.	Automobile parts	Joint development of valve gear mechanism parts related to engine
		Isuzu Motors, Ltd. and Izumi Automobile Co., Ltd.	Automobile	Joint development of ceramics for diesel engines
		Tomoura Electronics Co., Ltd.	Electronic parts	Joint research of temperature sensor which has processed the semiconductor element and ceramics into one body

[continued]

[Continuation of Table 2]

Name of enterprise	Type of business	Name of tieup partner	Partner's type of business	Contents of tieup
[Kyocera continued]	[Ceramics continued]	Eguro Tekko Co., Ltd.	Machinery	Joint development of bearings and spindles of precision small type NC lathes
		Fujikin Co., Ltd.	Machinery	Joint development of pipes made by fine ceramics
Hitachi Metals, Ltd.	Elec-tronic mate-rials, special steel	Nissan Diesel Motor Co., Ltd.	Machinery parts	Joint development of ceramics for diesel engines
		Koransha Co. Ltd.	Ceramics	Casting technology on fine ceramics
		Lucas Cookson Sialon Co.	(England)	Technical introduction to sialon
NGK Spark Plug Co., Ltd.	Ceramics	Riken Corp.	Machinery parts	Joint development of ceramics for diesel engines
Toshiba Corp.	Electric machinery	Toyota Motor Corp.	Automobile	Joint development of ceramic gas turbine engines
		Komatsu, Ltd.	Machinery	Joint development of ceramics for diesel engines
		Toshiba Ceramics Co., Ltd.	Ceramics	Joint R&D on production method of silicon nitride system silicon single system
		Koransha Co., Ltd.	Ceramics	Casting technology for fine ceramics
		Koyo Seiko Co., Ltd.	Machinery	Joint development of bearings made of silicon nitride
Asahi Glass Co., Ltd.	Ceramics	Nippon Carbide Industries Co., Ltd.	Chemistry	Full-scale tieup on electronic materials (established new company)
		Mitsubishi Jidosha Co., Ltd.	Automobile	Joint development of ceramics for automobile parts
		Nippon Kokan K.K.	Iron and steel	Joint development of silicon nitride sintered materials

[continued]

[Continuation of Table 2]

Name of enterprise	Type of business	Name of tieup partner	Partner's type of business	Contents of tieup
Kurosaki Yogyo Co., Ltd.	Ceramics	Shin-Niitetsu Steel Corp.	Iron and steel	Research on high strength of compound ceramics
Nippon Kagaku	Ceramics	Toyo Soda Manufacturing Co., Ltd.	Chemistry	Joint development of uses for partial stabilized zirconia (PSZ)
Toshiba Ceramics Co., Ltd.	Ceramics	Gasukuro Industry Co., Ltd.	Chemistry	Production of semiconductor related equipment and apparatus (established new company)
		Tokuyama Soda Co., Ltd.	Chemistry	Establishment of Tokuyama Ceramics Co., Ltd.
Nichias Corp.	Ceramics	Burner International Co., Ltd.	Machinery	Joint development for heat exchanger of ceramics fiber
Toray Industries, Inc.	Textile chemistry	Arusu Hamono Co., Ltd.	Metals	Joint development of zirconia system scissors and saws
		Matsushita Electric Works, Ltd.	Electric machinery	Joint development of zirconia made hair clipper blades
Kanebo, Ltd.	Chemistry	Kobe Steel, Ltd.	Iron and steel	Joint development of elemental technology on fuel cell
Nippon Glass Co., Ltd.	Ceramics	Cummings Co.	(U.S.)	Ceramics diesel engine
Shinagawa Refractories Co., Ltd.	Ceramics	Sauder Co.	(U.S.)	Technological introduction of ceramics fiber insulators
Firuton Co., Ltd.	R&D	Mitsui Shipbuilding & Engineering Co., Ltd.	Shipbuilding	Merchandise development of porous ceramics
Niigata Engineering Co., Ltd.	Machinery	Koransha Co., Ltd.	Ceramics	Joint development of injection molding machine sleeves

Source: Sakahiro Kimura, "FC Report," 2(6)2-14. 1984 and Yoshiro Nakamura NIKKO MATERIAL, 3(3)23-33, 1985.

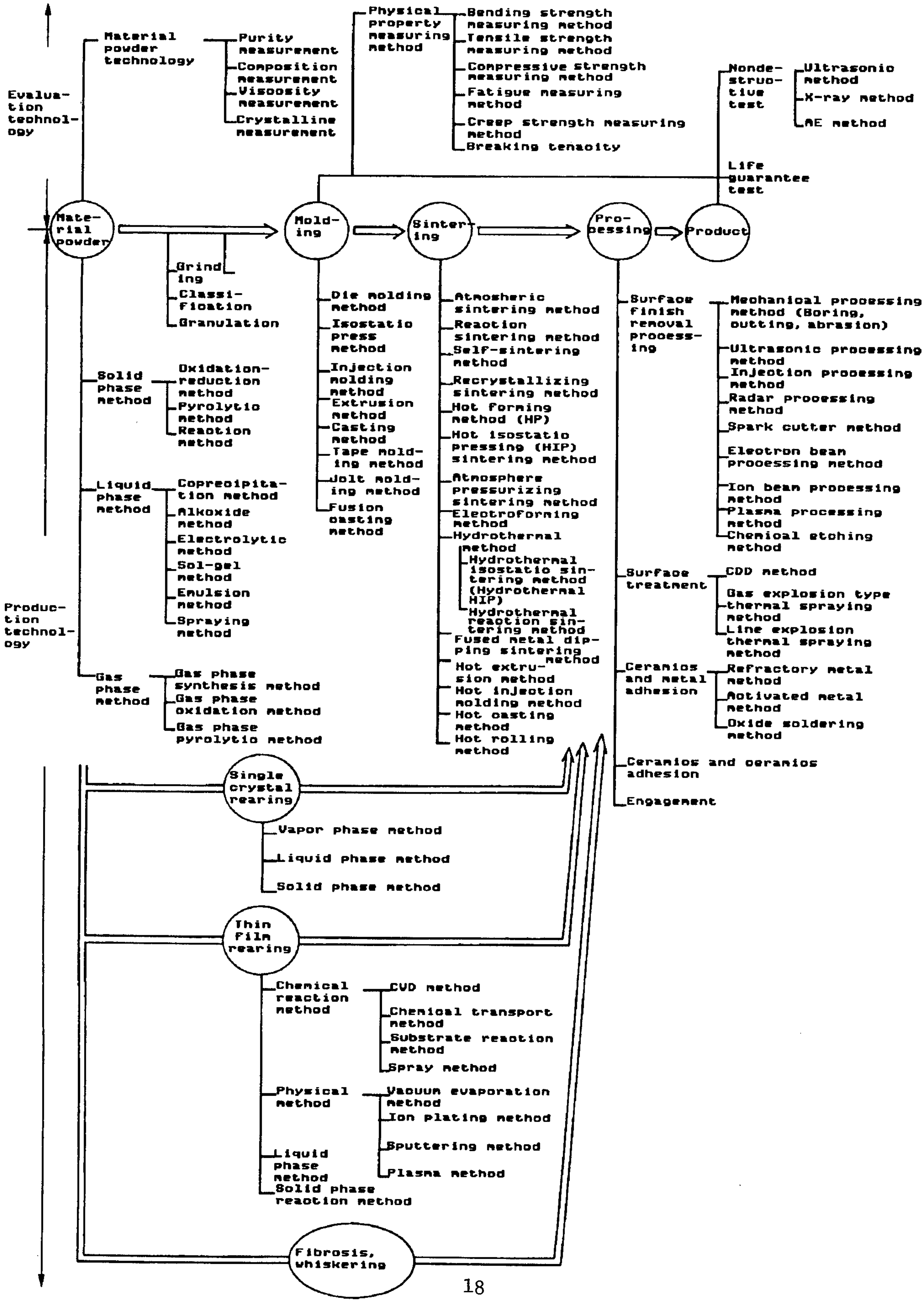
2) Performance goals

Among the 13 themes that have been selected for the Project of Basic Technology for Future Industries promoted by the Ministry of International Trade and Industry, fine ceramics and research on fine ceramics are being promoted by the Fine Ceramics Technical Research Association. As shown in Table 3, the performance reference value set by this association attaches importance to strength and the Weibull coefficient, with the target already having been cleared on the testpiece level and presently, efforts are concentrated on achieving the reference value for fine ceramics involving part shapes.

Table 3. Reference Performance Values Set by Fine Ceramics Technical Research Association

Performance goal	
Field	Reference value
High-strength materials	1. After 1,000 hours exposure to air under the high-temperature environment of more than 1,200°C, it should satisfy the following performance values under the same environment. (1) Reliability (Weibull coefficient) m: More than 20 (2) Strength (mean tensile strength) σ: More than 30 kgf/mm^2 2. It should satisfy the following performance value in a creep test of 1,000 hours in air under the high temperature environment of 1,200°C Durability (creep strength) σ: More than 10 kgf/mm^2
High corrosion-resistant materials	After 1,000 hours exposure to air under the high-temperature environment of more than 1,300°C, it should satisfy the following performance values under the same environment: (1) Reliability (Weibull coefficient) m: More than 20 (2) Corrosion resistance (oxidation weighing) less than 1 mg/cm^2 (3) Strength (mean tensile strength) σ: More than 20 kgf/mm^2
High precision wear-resistant materials	1. After 1,000 hours exposure to air under the high-temperature environment of 800°C, it should satisfy the following performance values: (1) Reliability (Weibull coefficient) m: More than 22 (2) Strength (mean tensile strength) σ: More than 50 kgf/mm^2 2. The items below are tested at ordinary temperatures and should satisfy the following performance values: (1) Wear resistance (specific wear amount): Less than 10^{-8}mm^3/kg·mm (2) Precision (surface smoothness) Rmax: Less than 2μm

Table 4. Production Technology and Evaluation Technology for Fine Ceramics



3) Important points for development

Since it is a new material, diverse elemental techniques require development (Table 4). Among these techniques the following items have become the important projects for development by the various ceramics manufacturers.

(a) Synthesis of material powders
(b) Tenacity improvement method
(c) Nearnet shape molding method
(d) High-speed grinding method
(e) Junction method with metals
(f) Nondestructive testing method of parts

Both the (b) tenacity improvement method for improving brittleness, which is the weakness of ceramics, and the (a) synthesis method of compound fine grain powders, which becomes necessary for the realization of item (b) mentioned above, are significant problems for future development.

Favorable results have been obtained for items (c), (d), (e), and (f), and it is believed that the development of production techniques to lower costs will be accelerated in the future.

4) Examples of development

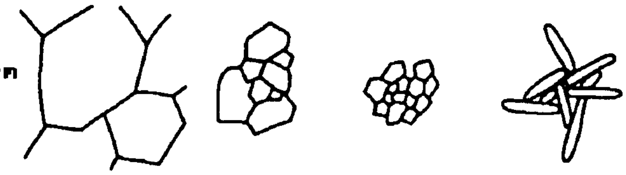
The development of production techniques for parts, together with the development of materials, is extremely important when putting fine ceramics to practical use. Among the favorable results already obtained, exemplification follows of the high-strength silicon nitride material, grinding wheel, junction method with metals and nondestructive testing method.

a) Development of high-temperature, high-strength silicon nitride material.

The size and form of sintered grains and the trend of their three-point bending strength at ordinary temperatures after atmospheric sintering using yttrium oxide as the sintering assistant are shown in Figure 2. Since rupture occurs easily along the intergranular layer, improvement in strength can be promoted by making the particle diameter of the fine size similar to that in metals. This is controllable through selecting the material powder and sintering conditions. Moreover, the rupture progress can be interrupted and a strength of 100 kgf/mm^2 at ordinary temperatures can be achieved by making it suitable-sized, needle-shaped particles.

This needle-shaped particle is obtained by utilizing the transformation of the silicon nitride crystal from the α form to the β form, utilizing the presence of the surrounding gas phase during sintering and by accelerating the particle growth toward a specific direction.

For high-temperature strength, a slip is generated by the applied stress and the strength lowers as the glass phase existing in the surroundings of the needle-shaped particles softens in the neighborhood of 850°C. Therefore, this glass phase has been changed by a crystal phase with a high melting point (for example, $Si_3N_4 \cdot Y_2O_3$), the decrease in strength has been prevented by



Crystal grain form				
Particle diameter (μm)	100	30~3	10~3	1×10
3-point bending strength (kgf/mm^2)	30	50	75	100

Figure 2. Sintered Structure and Strength

strengthening the intergranular layer and a silicon nitride capable of maintaining a high strength, even in temperatures up to 1,000°C, has been obtained.

b) Diamond grindstone

An example of a new diamond grindstone for ceramics is shown in Figure 3. In observing the surface of a poorly-cutting grindstone, we found that many abrasive diamond grains had dropped off. Therefore, the adhesion with the resin bond part was reinforced and a shock absorbing layer was provided for preventing vibrations from the wheel spindle, obtaining a grindstone with a performance improvement of about 10 times in the grinding ratio and about 5 times in efficiency over that of conventional grindstones. Furthermore, superior results have also been obtained for the roughness of the grinding surface.

c) Junction method with metals

The representative junction method that has been put to practical use is shown in Table 5. Emphasis has been placed on the chemical junction method rather than the shrink fit method due to the reliability, with the activated metal method being utilized for the turbo rotor and the copper direct method for the semiconductor ceramics substrate.

d) Nondestructive testing method

The biggest problem involving ceramics is brittleness and since the severity of the problem depends on the size of the defect, this method will be used to detect defects of about 30 μm on the surface and about 50 μm in the interior. It has not yet reached the stage whereby defect detection of this degree for both the surface and interior can be covered with a single device. Therefore, the ultrasonic method is especially used for detection on the surface while the X-ray-CT method is used for internal detection, and a photoacoustic method for use directly under the surface (for detection at about 0.01 mm from the

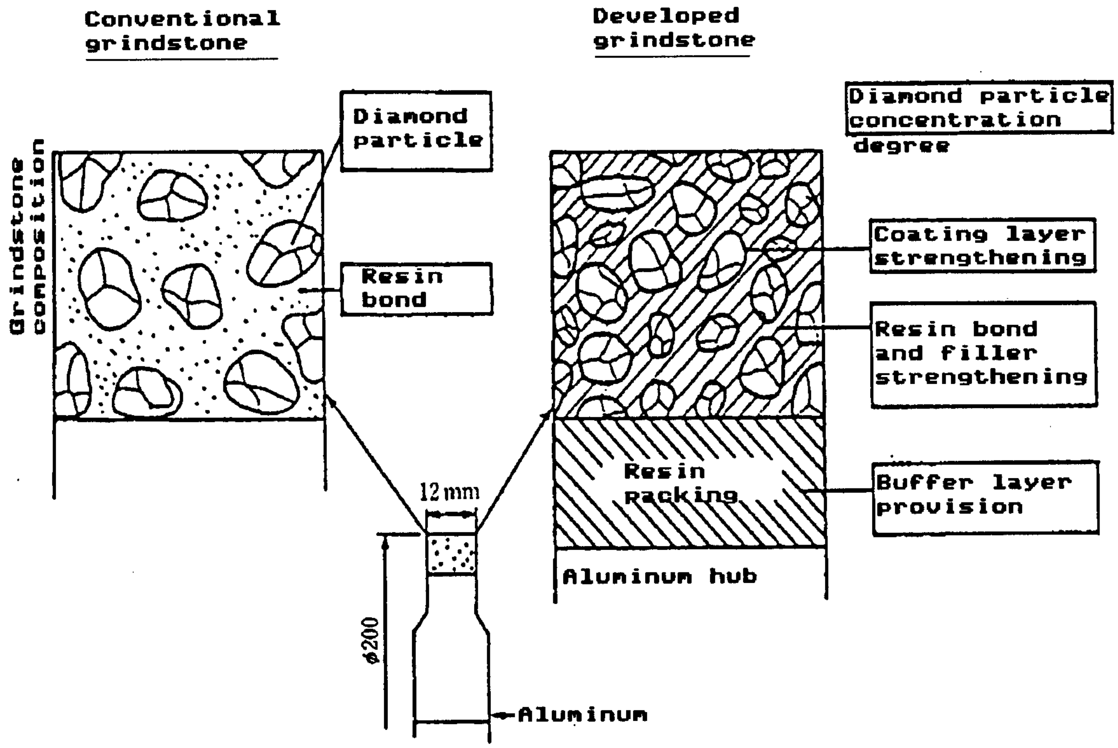


Figure 3. Diamond Grinding Wheel

Table 5. Examples of Junction Methods With Metals

Method (Junction medium)	Activated metal method (Cu-Ti)	Metallized method (Mo)	Direct method (Cu)	Shrink fit method
Shear strength junction part	30 kg/mm^2 300°C	10 kg/mm^2 300°C	9 kg/mm^2 300°C	--

surface) has been developed. In this method, the continuous laser beam is changed to a nonintermittent beam by the chopper and the sample surface is scanned. The sample is heated nonintermittently and a sound complying with the intermittent frequency is produced. This method is intended to detect the defect by processing the strength of the sound and phase change signal produced in the part with a defect. When the signal obtained using the sample, in which a crack has been entered as an artificial defect directly under the surface of the ceramics by pushing on the Vickers hardness tester, is processed, maps (Figure 4) corresponding well to the crack have been obtained when made of a suitable intermittent frequency.

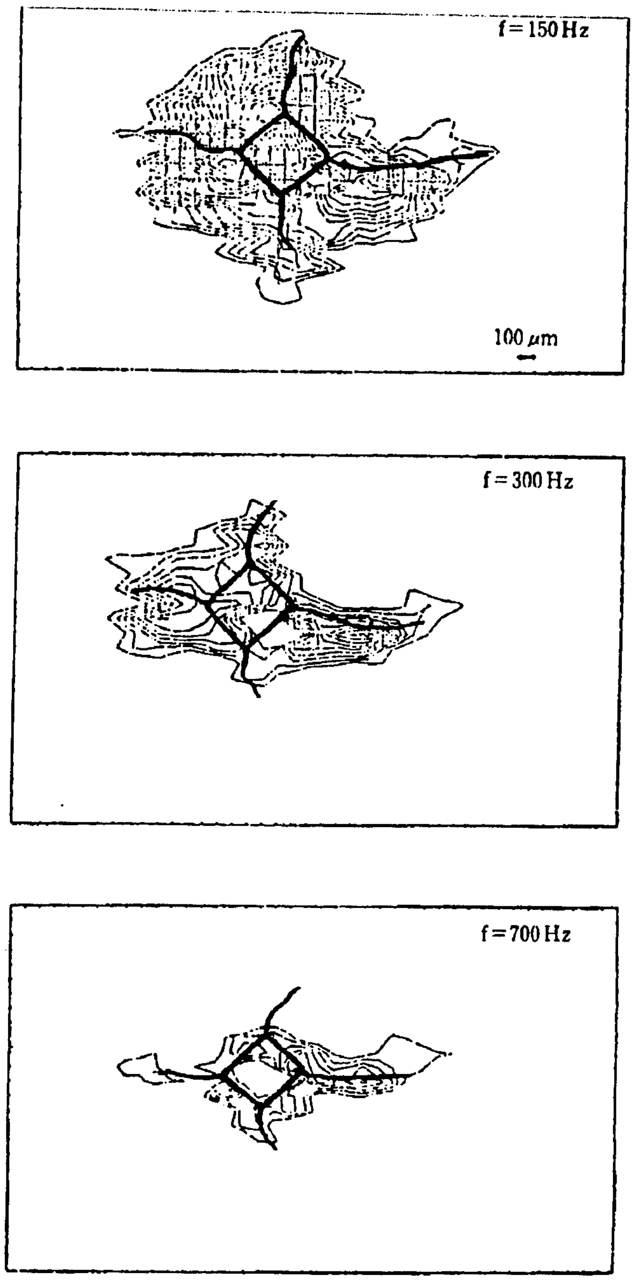


Figure 4. Photoacoustic Signal Image for Indent Made by Vickers Hardness Tester

4. Outlook for Practical Use

1) Application examples

An outlook is shown in Table 6 for putting fine ceramics to practical use in the mechanical structure field. Uses are diversified and when they are achieved, they will greatly influence the machine industry.

Table 6. Outlook of Practical Use of Structural Fine Ceramics Members (A) and Outlook of Industrialization of Important Techniques Related to Fine Ceramics (B)

Period	(Short-range)	(Middle period)	(Long-range)
	1985	1990	
Functions of features put to practical use	High-strength wear resistance Corrision resistance Erosion-proof Strength against high temperatures		
(A) Name of concrete members to be put to practical use (examples)	.Heat exchanger (clean gas up to 1,000°C) .Mechanical seal .Various nozzles .Bearings .Abrasives .Grinding and mixing equipment members .Cutting tools .Jigs for testing and inspecting equipment and apparatus ·Gas ignitors .Valves .Wire drawing dies .Extrusion dies .Mandel .Aluminum diecast machine members	.Heat exchanger (Corrosive gas up to 1,200°C) .Turbo charger ·Noncooled diesel engine parts Piston liner Piston cap Head plate Value seat Subcombustion chamber Exhaust pipe coating . Turbine static parts Combustor Shroud .Turbine rotor ·Slurry pump ·Tube burner .Heater .Geothermal well drilling equipment members	.Minimum friction and insulation diesel engine Piston Bearing Combustion chamber Exhaust system .Gas turbine engine Starter Rotor Recuperator .Aircraft propulsion engine .MID power generating members .Fusion reactor No 1 reactor wall .Stalling engine .Iron diecast machine members
(B) Name of concrete techniques to be industrialized (examples)		.High purity, easily sinterable material powder production technique .Low cost HIP technique ·Precision cutting and machining techniques of ceramics .Establishment of nondestructive test techniques ·Junction techniques of ceramics .Ceramics fiber production techniques ·Production techniques compound materials using ceramic fibers ·Ceramic compound material processing techniques	.Pressureless sintering techniques of high density sintered material ·Establishment of material life estimating method .Establishment of ceramics design techniques ·Production techniques of high tenacity ceramics ·Ceramic compound material junction techniques .Production techniques of high temperature and high strength ceramics .Production techniques of high temperature and high acid-resisting ceramics

Source: Ministry of International Trade and Industry, Fine Cernaics Office, Editor, "Outlook and Problems, "Outlook and Problems on Fine Ceramics, New Material for the 21st Century," August 1984

2) Ceramic engine parts

A large market can be expected for successful ceramic engine parts, however, the risks are great, and up to what extent ceramic parts can be put to practical use remains a future problem in addition to the necessary, long-term development costs. Nevertheless, there is a strong possibility that a new, highly efficient engine, making the most of the special features of various ceramics, will be developed. An example of the concept for diesel engine improvement in the United States is shown in Table 7. It is also a certainty that an engine made totally of ceramics will not appear, as ceramics will be used in limited parts only and will be used in conjunction with metals.

Table 7. Example of Concept for Diesel Engine Improvement

	Present engine →	W/turbo →	Realization of heat insulation →	Realization of low friction →	W/botton engine
Heat loss (percent)	62	59	52	44	37
Fuel cost (g/HP·h)	160	146	132	118	103 (35 percent reduction of present engine ratio)

Various companies are presently trial manufacturing and repeating tests on ceramic parts, such as the hot chamber, turbo rotor, valve system, piston, head, cylinder liner, port liner, bearings, etc. As shown in Table 8, ceramic parts for automobile engines currently being merchandized in Japan are all of the silicon nitride system. Although each part has not been produced in great quantity, no special discrepancies have been noted, and it has been observed that the fact that parts, though few in number, have been installed in the turbo rotor, with its severe demands, is significant for future ceramics use in machine parts.

In addition, attempts are currently being made to decide which parts should be made by ceramics next, however, it is observed that a steady, though moderate application, preferably striving for long-life and maintenance-free sliding system parts, will progress in the future, eventually enjoying full-scale practical use.

3) Far-reaching effects

Since the positive achievements exhibited by conventional metals and plastic materials are great, there is no intention to replace them with ceramics, but instead, both will coexist. However, the far-reaching effects will be far realized in the machinery field when ceramics that are strong, light, rust-free and not easily worn are put to practical use. These effects will extend from the realization of high precision and long life, brought about by the

Table 8. Conditions for Merchandizing Ceramic Parts for Automobile Engines (Announcements made by domestic newspapers)

Period	Parts	Material	Automobile manufacturer
1981	Glow plug	Si_3N_4	Isuzu Motors, Ltd.
1983	Subcombustion chamber	Si_3N_4	Isuzu Motors, Ltd.
1984	Subcombustion chamber	Si_3N_4	Toyota Motor Corp.
1984	Rocker arm pad	Si_3N_4	Mitsubishi Motor Co., Ltd.
1985	Turbo rotor	Si_3N_4	Nissan Motor Co., Ltd.
1986	Subcombustion chamber	Si_3N_4	Mazda Motor Corp.

improvement in wear resistance of machine tools, measuring instruments, valves, pumps and bearings, in addition to the automobile engine parts mentioned above, up to the expansion of utility under severe environments. Moreover, the possibility of contributions toward resources is also being seriously considered in Japan.

4) Steps for putting to practical use

Following the success of cutting tools that are already being used commercially, a market is now being prepared for rolls, dies, pumps, valves, bearings, etc., in the fields of wear resistance, corrosion resistance, and heat resistance. Then, after the engine parts enter full-scale use 3 or 4 years later, it will take 10 years to develop gas turbines for power generation, which require a long-life guarantee, and a staged market development extending through the 21st century will aim at geothermal wells, marine resources searching equipment and nuclear reactor parts.

5) Problems involving practical use

In summary, the material parts manufacturers problems include the securement of reliability and reductions in production costs, and the user's problems include establishing a design technology in which the new materials can be used in conjunction with conventional materials.

Evaluation methods have not yet been standardized and the tenacity is especially insufficient. Therefore, when observed from the user side, the fact that the material data necessary for design is insufficient makes current use of this material unreliable. Of these problems, the ones requiring immediate attention are the international standardization of the evaluation method and the establishment of a material data bank, and it can be expected that rapid progress will be made in the future regarding these two problems involving cooperation between the newly-established Japan Fine Ceramics Center and the Fine Ceramics Association.

The following points can be listed as the priority items regarding reliability and cost:

Securement of Reliability

--Production techniques of homogeneous parts
--International standardization of evaluation method
--Accumulation of data on characteristics
--Junction method with metal parts
--Quality guarantee method

Reduction of Production Cost

--Mastering of cheap material powders
--Reduction of production time
--Yield improvement
--Reduction of inspection cost
--Repair and recycling method for defective products

5. Future Development Problems

The development of structural ceramics up to now has placed emphasis on "Homogeneity" and continued improvements in strength and dispersion, and favorable results have been achieved in each of these areas. In the future, while using these favorable results as the foundation, it is desired that progress be directed toward the realization of highly-tenacious materials and toward surface modification during processing by introducing "Nonhomogeneity" under a finer level.

Homogeneity realization has been promoted centered around making the crystalline structures homogeneous and eliminating defects, such as inclusions, ores, etc. The exclusion of defects of more than 39 μm has been the target. Therefore, as a result of promoting defect control throughout the entire process, extending from the particle size distribution of the starting material powders to the surface processing flaws at the finish, a production technology that does not allow defects of more than approximately 50 μm has been realized and the detection of defects has now become possible.

Now, using ceramics controlled in such a manner as the basis, the method of introducing a microscopic crack of about 10 μm by adding, for example, whiskers, etc., of less than 10 μm, to this has been adopted for controlling the branching of the development on the main crack, and it is now thought a possibility that the tenacity value can be improved two to three times by this method.

On the other hand, research is being conducted involving the surface modification of ceramics in which the fitting is eased in its initial use and the generation of small cracks can be avoided when it is applied to a mechanical seal, etc., since a softening layer can be formed by injecting for example, heavy metal ions onto the silicon carbide surface, thereby changing it into an amorphous layer.

Similarly, as metals acquire diverse uses by means of various surface treatments, it can be expected that the development of the surface modification method in ceramics by the above-mentioned method of injecting heavy metal ions, etc., will exhibit a suitable effect when used in conjunction with the tenacity improvement of the base metal ceramics. The overcoming of brittleness, which is the main weakness in ceramics, is the chief problem left for future development, and I believe that now is the time to challenge this problem.

BIBLIOGRAPHY

1. Japan Machinery Federation, Material Development Special Committee Report, "Material Development in the Near Future Society," September 1976.

2. Petzow, Dr. G., Fine Ceramics Association Special Lecture Meeting, 28 May 1976.

3. Kimura, S., FC REPORT, Vol 2 No 6, 1984, pp 2-14.
   Nakamura, Y., NIKKO MATERIAL, Vol 3 No 3, 1985, pp 23-33.

4. Ministry of International Trade and Industry, Consumer Goods Industries Bureau, Fine Ceramics Office, "Status Quo and Policy of the Fine Ceramics Industry," 1976. p 49.

5. Ministry of International Trade and Industry, Consumer Goods Industries Bureau, "Status Quo and Policy of the Fine Ceramics Industry," 1976, p 20.

6. Osaka Kongo Grindstone Manufacturing Co., Ltd., "FC Diamond Wheel Catalog," 1985.

7. Japan industry Technological Promotion Association and Fine Ceramics Technological Research Association, Basic Technology for Future Industries Symposium, 1985.

8. Ministry of International Trade and Industry, Consumer Goods Industries Bureau, Fine Ceramics Office, editor, "Outlook and Themes for New Material Fine Ceramics for the 21st Century," 1984.

9. Westwood, Dr. A.R.C., Fine Ceramics Association Special Lecture Meeting, 13 November 1984.

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ITEMS FROM NATIONAL AEROSPACE LABORATORY NEWS JANUARY 1987

Balance for Wind Tunnel

Tokyo KOGIKEN NYUSU in Japanese Jan 87 pp 2-3

[Article by Hideo Sawata, 2d Aerodynamics Division

[text] Heat-Insulating Type Externally-Inserting Balance for Low-Temperature Wind Tunnel

The low-temperature wind tunnel of the National Aerospace Laboratory [NAL] has been operating for more than 260 hours or so to date since the start of its low-temperature operation in 1983. During this period, valuable technical data on the operation of low-temperature wind tunnel have been acquired in large numbers. At present, the operation of the NAL low-temperature wind tunnel is being automatically conducted practically by the computer. As far as the operation is concerned, it differs little from the ordinary wind tunnel, and is so structured that it can easily produce inside the measuring unit a flow of the fixed total temperature, total pressure and Mach number. During this period, in addition, research on many low-temperature wind tunnel related basic measurement technologies under the low-temperature environment, such as the measurement of stationary pressure and temperature, the schlieren photographing, and the lighting of model, has been jointly conducted.

Form the last fiscal year when the prospect of the operation of the NAL low-temperature wind tunnel being automated became certain, the development of a balance for low-temperature wind tunnel was started. In order for the low-temperature wind tunnel to be used in the same way as the normal-temperature wind tunnel, it is considered that technology of the balance to measure the force applied to the wind tunnel test model is most important among the measurement technologies under the low-temperature environment.

In the development of the balance for low-temperature wind tunnel at the NAL, a heat-insulating type externally-inserting balance device was first test manufactured as a balance device that can be used for the 0.1-m x 0.1-m NAL low-temperature wind tunnel. Since it is of the heat-insulating type, the temperature lowering of the balance itself is avoidable, and as the balance material the existing material can be used. In addition, balance calibration equipment, etc., under the low-temperature environment become unnecessary. Further, as it is of the externally-inserting type, it is not necessary to miniaturize the balance device.

The heat-insulating type externally-inserting balance is fairly easily developed as the balance for low-temperature wind tunnel, but some problems awaiting solution, which are peculiar to this type, have also been considered. For instance, in the heat-insulating type balance, heat insulation is accomplished by preparing a heat-insulating layer around the balance. For accurately measuring the force applied to the model, the aerodynamic force must be carried exactly up to the sensitive element of the balance; thermally it must be insulated between the model and the balance.

The heat-insulating type externally-inserting balance designed and manufactured by taking various measures for solving these problems is the one shown in Figure 1 [omitted]. The photograph depicts the state of having assembled the angle changing unit of model's angle of incidence, and the balance element section, etc., inside the heat-insulating vessel. In order that the temperature of the balance element be kept at 20°C during the operation of the low-temperature wind tunnel, the electric current flowing in the electric heater attached to the inner wall of the heat-insulating vessel is always controlled.

As the capacity of the balance, the lift is 100 N, the drag is 10 N, and the pitching moment around the balance center is 1 nm. As to its accuracy, the nonlinearity is 0.3 percent F S, the hysteresis is 0.6 percent F S, and the temperature dependency is 0.01 percent F S/°C with regard to the zero point and 0.05 percent Reading/°C with regard to the sensitivity.

According to the test result, the zero-point changes with regard to the lift and the drag during the operation of the low-temperature wind tunnel conducted by lowering the total temperature down to -180°C, keeping the total pressure at 150 kPa, and changing the Mach number from 0.4 to 0.9 were less than 0.5 percent. Further, it has been confirmed that the zero-point change of the pitching moment is less than 0.7 percent F S.

The model now used for performance appraisal of the balance for the NAL low-temperature wind tunnel is the AGARD-B model with a wing span of 30 mm. In the measurement section, the upper and lower walls are porous walls and the side wall is a solid wall. For the model supporting method, the shoring was employed, but as shown in Figure 2 [omitted], the fairing covering the shore is very thin, measuring 3 mm in thickness and 282 mm in length. This method slightly resembles the model supporting method of the plate mount system.

In the model test using the NAL low-temperature wind tunnel, the representative chord length of the model was 17.3 mm. In the case where the total temperature at -180°C, the total pressure at 150 kPa, and the uniform flow Mach number at 0.70 in the wind tunnel, the Reynolds number became 1.7×10^6. On the other hand, in the test of the AGARD-B model of 300 mm in wing span conducted by using the NAL 2 m x 2 m transonic wind tunnel, the Reynolds number in case of the same uniform flow Mach number of 0.70 became 1.6×10^6. In other words, in respect to the Reynolds number, the value in the test conducted by the NAL low-temperature wind tunnel and that in the test conducted by the 2 m x 2 m transonic wind tunnel nearly agree with each other. This fact indicates clearly how the low-temperature wind tunnel is superior in the capability of producing a flow corresponding to the high Reynolds number.

According to the dynamic law of similarity, in two tests using similar models concerning the Mach number and the Reynolds number, when conducting the tests so that the values of the two agree with each other, the aerodynamic performances of the models become the same when neglecting the effects attendant upon the wall interference and the model support interference. In Figure 3, for example, the results of the two tests using the NAL low-temperature wind tunnel and the NAL 2 m x 2 m transonic wind tunnel (TWT) well agree with each other. Judging from this result, the heat-insulating type externally-inserting balance for the NAL low-temperature wind tunnel, which was test manufactured this time, is a balance for low-temperature wind tunnel that can fully be used even under low-temperature environment.

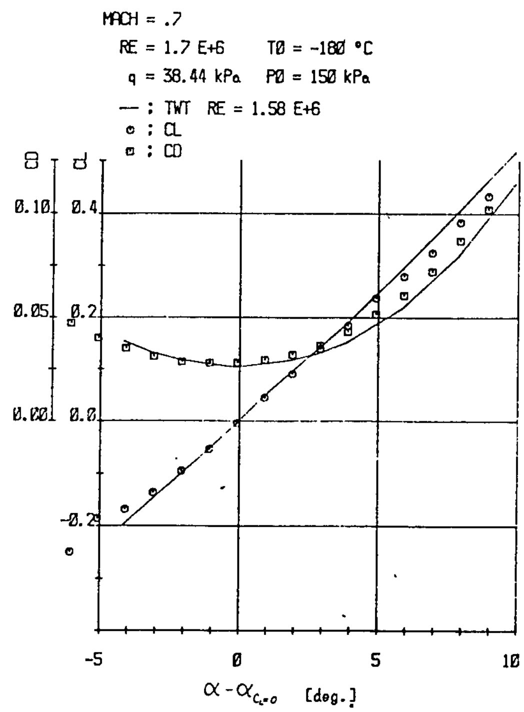

Figure 3. Measurement Result of Aerodynamic Performance of AGARD-B Model

Fracture Observation of Al-Li Alloy

Tokyo KOGIKEN NYUSU in Japanese Jan 87 pp 4-5

[Article by Yoshiaki Tsunoda]

[Text] Aluminum-lithium (Al-Li) alloy is gaining attention as a promising new material for reducing the airframe weight of aircraft, and its active development and mass-production program by Western light-metal makers are in progress. This material aims at lowering the density by about 10 percent, keeping the strength at the same level, and further improving the modulus of elasticity by about 10 percent as compared with the existing aluminum alloys (2024-T4, 7075-T6, etc.) for aircraft.

At present, the NAL, procuring 1-mm and 1.6-mm thick Al-Li alloy plates (DTD-XXXA: material corresponding to aluminum alloy 2024) of Britain's Alcan Co., is studying the basic strength characteristics of material by conducting tests on their static strength, fatigue, fracture toughness, etc. In this article, as we have conducted various fracture observations by the scanning electron microscope (SEM) for collecting basic data that will be useful for the elucidation of the fracture characteristics and the cause of breakage of the actual aircraft as a part of a series of research, we will introduce a part of them.

Figure 1 [omitted] shows the fracture due to static load taken by photomicroscope of 5,000 magnifications. Parallel fibrous stripes on the surface of the plate of the sample material are characteristic, but tiny depressions called dimples can also be observed. However, it is known that the development of dimple is insignificant.

Figure 2 [omitted] shows the fracture in the region of making a stable growth form the fatigue pre-crack tip as the initial notch to a certain critical crack length with the increase of the applied load in the fracture toughness test. Seen from a macroscopic point of view, many dimple patterns, as in the case of static load, can be observed on the flat fracture. As in the case of Figure 1, the development of dimple is insignificant also. From Figures 1 and 2, it is shown that the static fracture is brittle.

Figure 3 [omitted] shows the striation that is characteristic of fatigue fracture, and one parallel striped pattern is formed in every one cycle of applied load. The striation interval in this case is 1.34 μm, but it agrees relatively well with the macroscopic crack development speed in a range of 10^{-4} to 10^{-3} mm/cycle. Another characteristic here is that cracks seeming to be intercrystalline cracks are observed on the fatigue fracture.

Figure 4 [omitted] shows the corrosion fracture taken by photomicroscope of 1,000 magnifications. We have used black water-color ink for facilitating the measurement of the crack development in the fatigue test, and observed a situation of filmy corrosion products coming out and covering the overall fatigue fracture in a short period. This material is highly corrosive, and therefore, this point must be fully taken into account in designing. We have applied ultrasonic cleaning to these corrosion products for about 10 minutes, but failed to remove them.

Computation of Flow Method

Tokyo KOGIKEN NYUSU in Japanese Jan 87 pp 5-7

[Article by Kazuhiro Nakahashi, Motor Division]

[Text] Computational aerodynamics to simulate the flow of air by computer has made rapid progress in the last 10 years or so; at present, even predictive computation of the flow around the overall aircraft is becoming possible. In the computation itself, however, there are still many technical points remaining to be solved. Particularly when it comes to the computer of the flow around the actual form, experienced researchers currently are

devoting enormous labor and time to the division of flow field, computation of flow by the computation lattice, and the output of the computation results. Thus they are, so to speak, conducting computation on a made-to-order basis. Hereafter, computational aerodynamics will probably be put to use more and more as an engineering tool. To that end, however, how simply and efficiently the computation can be conducted is important, and it is necessary to improve the technology of computational aerodynamics to the extent of being capable of conducting easy-order computation, and even ready-made computation that can be conducted only by giving the form data and computation conditions. This article will introduce one of our newly designed approaches to it.

The computation methods now used for flow computation can probably be divided into the finite difference method to conduct computation by subdividing the flow field by the regularly arranged computation lattice (structured lattice) and the finite element method by the unstructured lattice. The finite difference method, whose computation efficiency has been markedly improved in recent years, is being widely used for the computation of flow. However, because of its use of the structured lattice, it is difficult to form the lattice for the flow around the complicated object form or when there are many objects in the flow field. In contrast to this, the finite element method is full of form adaptability because of its use of the unstructured lattice; it has thus far often been used for internal flow computation, etc. However, it is still inferior to the finite difference method in computation efficiency.

Thus, a hybrid method to make the most of the advantages of the two computation methods is attempted. In other words, the flow near the object, for which the volume of computation is largest, is solved by the good-efficiency finite difference method (FDM), and to the remaining region, the finite element method (FEM) full of form adaptability is applied. In this computation method, the overall lattice formation is simplified by the flexible FEM lattice, and the wide availability of software capable of computing various flow fields without touching the main part of the computation code can also be utilized.

Figure 1 [omitted] shows the computation lattice of turbine cascade, and Figure 2 [omitted] shows the comparison of its computation result with the test result (schlieren photograph). Shown in Figure 3 [omitted] is the surface lattice for the computation of three-dimensional viscous flow of the engine air inlet. The viscous flow regions near the fan cowl and the spinner are covered with the finite difference lattice, and the two are connected by the tetrahedral finite element lattice. Figure 4 [omitted] is the meridional equal Mach line chart.

Computational aerodynamics is expected to become one of the great driving forces for the development of innovative aircraft, and it is believed that we can meet that expectation pretty well by constructing hereafter a highly flexible computation method employing a wider range of computation technologies.

European Trends Regarding Space Plane

Tokyo KOGIKEN NYUSU in Japanese Jan 87 pp 7-8

[Article by Shigeaki Nomura, 1st Aerodynamic Division]

[Text] The committee (chairman: Professor Shigeo Kobayashi, Department of Technology, Tokyo University, entrusted with the FY 1985 and 1986 National Space Development Agency business) for "research on space shuttle transport system" established in the Aerospace Institute of Japan decided to dispatch a survey team to Europe, as a part of its FY 1986 survey work, to conduct a detailed survey on the space shuttle transport system being planned and studied there. The survey team, led by Chairman Kobayashi, included Nomura (NAL) [author of article], Kubota (professor of the Department of Technology, Tokyo University), Suzuki (Space Plane System, Tsukuba Space Center, National Space Development Agency), Honda (Nagoya Aerospace Equipment, Mitsubishi Heavy Industries, Ltd.), Okumura (Aircraft Aerodynamics, Kawasaki Heavy Industries, Ltd.), and Takiyama (Space Development, Ishikawajima-Harima Heavy Industries Co., Ltd.). Two other persons, Tomita (Space Planning Section) and Hasegawa (Space Development Section) of the Research and Development Bureau, Science and Technology Agency, also accompanied them. In total, nine members conducted the survey on the related organizations and enterprises in Europe. The survey period was 14 days, including travel time, from 18 November to 1 December 1986. The countries visited were Britain, France, and West Germany. The itinerary included the following organizations:

British National Space Center (BNSC, London)
British Aerospace Co. (Stevenage, suburban London)
HOTOL symposium (London)
Rolls-Royce Motors, Ltd. (Bristol)
French Space Center Headquarters (CNES, Paris)
European Space Agency Headquarters (ESA, Paris)
Dassault Breguet Co., (Saint-Cloud, near paris)
Aerospatiale Co. (Mureaux, near Paris)
German Aerospace Laboratory (DFVLR, Cologne)
MBB-ERNO Co. (Munich)

The research and development of the space plane has a long history such as the hypersonic test vehicle by the U.S. X series and the rocket aircraft program of Dr Zenger of West Germany, but it had been interrupted by the U.S.-Soviet manned space development race that started with the rocket plus manned capsule system of the Soviet Union. However, since the space shuttle orbiter was developed as a repeatedly usable winged recovery vehicle aimed at lowering the cost of space development, studies on the winged space plane program and concept, including the U.S. post-shuttle program, have been actively conducted in various countries of the world. That trend was spurred by the announcement of the New Orient Express program in President Reagan's annual State of the Union Message to Congress in January 1986. At the same time, various space projects from the hypersonic aircraft to the space shuttle transport experienced technical, economic, and political complications. Particularly in Europe, France advocated early on a system to mount the Hermes winged plane on the upper stage of the Ariane 5-type rocket as payload; Britain advocated the

single-stage horizontal take-off and landing plane HOTOL; and Germany advocated first the Horus winged rocket as the second stage of the Ariane 5-type rocket, and then the two-stage type HOTOL (Sanger) to mount the Horus winged rocket on a winged mother plane which can become also a hypersonic plane. These nations are all conducting energetic activities to secure ESA's approval for development of these as the European projects. The contents of these projects and their positioning in the overall space development program, and their future developments will have a great effect also on the way a space transportation system extending into the 21st century in Japan should be. Detailed technical information and complicated political information about these nations cannot be fully acquired in Japan. These considerations form the background and objective in the aim and background for sending the Europe survey team at this time.

Since the formal report of the survey team will be compiled as a committee report, further details must be left until the final report.

At each place, we exchanged information by conducting a presentation on the status and prospects of the space plane in Japan by team leader Kobayashi, the study at NASDA by Suzuki, the technology for the future by Nomura, the HIMES study at the ISAs by Kubota, and the MHI LACE engine study by Honda, omitting portions according to the time allowed.

The BNSC is a government agency organized in 1985 to integrate activities of the British space-related organizations. It is enthusiastic in promoting the HOTOL as a means of helping Britain recover from a belated start in the space transportation system development in Europe. At its headquarters, we held conferences on the British way of thinking, the positioning of the HOTOL, etc., with five persons, including J. Leeming (associate of President R. Gibson).

At British Aerospace Co., we heard details on HOTOL technology, with the exception of the engine from two representatives of Conchi and Parkinson, called the originator of the HOTOL concept.

At the HOTOL symposium, which was sponsored by the British Interplanetary Society, HOTOL-related policy, concept, aerodynamics, structure, cost appraisal and engine were revealed. Attendance was well beyond expectation, about 200 participants, and there were also exchanges of bitter words with the participants from the ESA who support the Hermes.

At Rolls-Royce Motors, Ltd., we expected to have an introduction to the substance of the new engine technology that is being given worldwide critical attention, but we were unable to get any information because it is considered secret. Even Rolls-Royce did not know when it could be revealed. However, we studied and observed and heard explanations of the ramjet altitude combustion tester and engine technology in general.

At the CNES headquarters, we discussed Hermes technology in general and reliability of the Ariane 5-type rocket, etc., from Desloire, the launch director who came from CNES-Evry.

At the ESA headquarters, we held talks with representatives of the ESA transportation-system project from Australia, Italy, and France. We talked with them mainly about the positioning of the preliminary study of the Hermes project now underway by the ESA, its future schedule, its relation with the HOTOL and (Sanger), and so forth.

Dassault Breguet has a great many achievements in aircraft manufacturing, and is chiefly in charge of studying the Hermes airframe. We held discussions with many engineers, including the person in charge of the Hermes program for the company. We heard explanation of aerodynamics, structure, and protection against heat of the Hermes airframe; we also studied and observed composite material main wings, metal heat-insulating material, aerodynamics by CAD/CAM, structural design, etc. of other aircraft.

Aerospatiale Co. is the main firm in charge of France's space development, such as system integration of the Ariane rocket series. We heard explanation on the Hermes, Ariane, etc., from the person responsible for the Hermes program, the person in charge of design of the Ariane 5-type rocket, etc.; and we visited the Ariane 3-type liquid fuel tank manufacturing and assembling plant.

At the DFVLR (Cologne), we were unable to hear details of the (Sanger) program because of a conference of its main members held in Gottingen, but we did hear explanation of aerodynamics, wind tunnel, in-flight simulator, material, etc.

MBB-ERNO is the promoter of the winged plane (Sanger) of Germany. We talked with many persons in charge, including the vice president of the company, about the Columbus program and the space development infrastructures such as the European hypersonic vehicle (EHV), the Hermes, the HOTOL, and the (Sanger). We also visited the TVSAT satellite assembling plant.

With a tight schedule of visiting 10 places in a short period, we were able to acquire considerable information through good teamwork under the leadership of Kobayashi. We owe this to assistance from all quarters concerned, and want to express our thanks to them here.

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BEAM CONTROL TECHNOLOGY FOR LASER PROCESSING DEVICE

Tokyo OPTRONICS in Japanese Apr 87 pp 89-94

[Article by Haruhiko Nagai, Laser Study Group 1, Industrial Machine Development Division, Applied Equipment Research Laboratory, Mitsubishi Electric Corp.: "Light Beam Control Technology for Laser Machining"]

[Text] 1. Introduction

Laser machining represented by CO_2 laser and YAG laser (yttrium-aluminum-garnet laser) machining is a thermal machining process. Thermal control is an important factor in determining laser machining quality.

Thermal control required in laser machining, roughly classified, involves controlling two different properties of the light beam--the laser beam output power density and material to be processed and the plane of polarized light wave affecting the absorption characteristics with reference to the work to be machined, especially metallic material. Control of the output power density is divided further into spatial control and temporal control. Temporal control is the operation of controlling the pulsed laser output, and the spatial control the transverse mode, beam convergence, etc. Controlling the plane of polarized light wave, another part of thermal control, is important especially in cutting off metallic material. As for light polarization, the circularly polarized wave must be provided in order to carry out high-quality cut-off of a metallic workpiece.

In addition to the mentioned thermal control, light beam transmission control technology, used as a type of beam control, is also important in the laser machining equipment. In laser machining, it is important to guide properly the laser beam to a desired position of the workpiece, without causing degeneration of the beam quality and substantial loss of energy. For this reason, it is necessary that an optical transmission system based on light diffraction theory be designed. Optical fiber transmission technology for laser machining was put into practical use by the YAG laser. The operational flexibility of such a transmission system has greatly expanded usefulness of the YAG laser.

The laser machining process is being increasingly used in the field of minute removal machining, such as in cutting-off, perforation, surface-reforming, or in trimming, scribing, marking, repairing, etc. Research and development

activities of chemical minute machining process using an excimer laser are being broadened.

This article exclusively deals with beam control technology associated with thermal lathe machining of a nonchemical nature.

2. Temporal Control

By controlling the pulse, the laser beam output power density (w/cm^2) can be freely controlled. It is necessary to use the pulse control in order to perform power density control in laser thermal machining. The pulse control includes actions of controlling pulse energy, pulse width, duty, recurring frequency, etc. Table 1 shows beam characteristics of the CO_2 laser and the YAG machining laser.

Table 1. Characteristics of CO_2 Laser Beam and YAG Laser Beam

Item	CO_2 laser	YAG laser
Wavelength	10.6 μm	1.06 μm
Successive oscillation output	26.5 kw (maximum)	1 kw (maximum)
Pulse output	o Successive pulse-discharge excitation method (enhanced pulse, super pulse) Peak value 2.5-4 kw (max) Repetitive 1-5 kHz (max) Pulse width 100 μm, continuously o TEA CO_2 laser: Peak value 1-2 MW (max) Repetitive 200-300 Hz (max) Pulse width 100-150 ns	o Successive excitation method Ultrasonic Q-switch pulse Peak value ~20 kw (max) Repetitive ~50 kHz or less (max) Pulse width 150-200 ns o Pulse excitation method Q-switch pulse Peak value ~10 MW (max) Repetitive 50 pps Pulse width 10-40 ns Normal pulse Peak value several kw Repetitive 50-200 pps
Angle of	Single mode (TEM_{00} mode) 1-2 mrad Multimode (TEM_{mn} mode) Several mrad ...stable type beam resonator Ring mode 1-3 mrad ...unstable type beam resonator	Single mode (TEM_{00} mode) 1 mrad Multimode (TEM_{00} mode) several mrad
Diameter of gathered beam spot	50-500 μm	20-50 μm

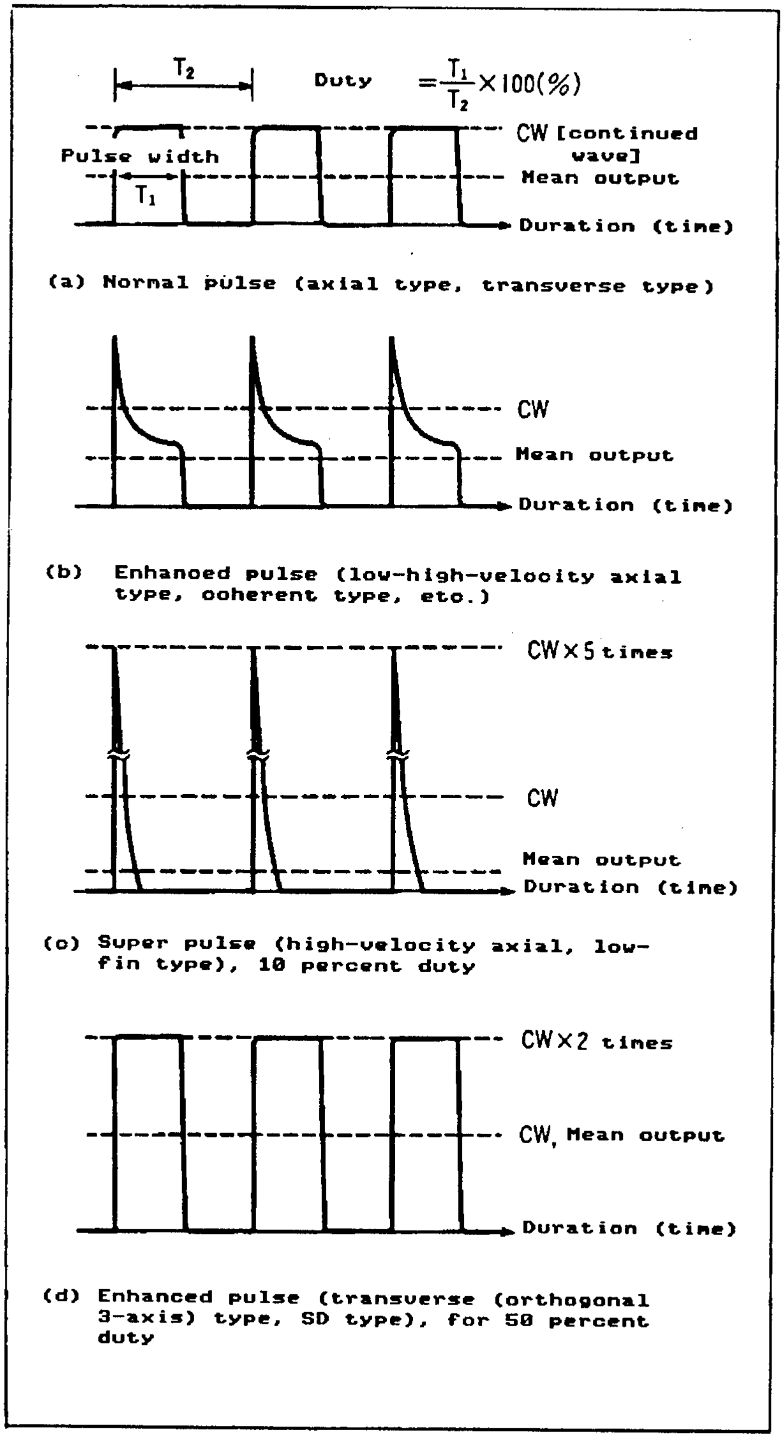

Figure 1. Pulse Output Patterns of Machining Purpose CO_2 Laser

The CO_2 laser is pulsed by an electrical discharge. This discharge-pulsing is divided into two laser actions: pulse discharge excitation, made mainly from successive oscillations, and TEA (transversely excited atmospheric) laser of high peak value caused only from recurring pulse oscillations. The former is the pulse successive output laser of 0.5 to 1.0 kw by the on-off of discharge. In addition to this normal type of pulsing, there are other types of discharge pulsing: enhanced pulse and super pulse. In these types, by discharging

output of a higher density than the successive oscillating power output, the pulse output obtainable is two to five times the values resulting from the successive output. Figure 1 shows the forms of pulses for CO2 laser machining.

Pulse control like this is a technology indispensable for high-quality machining, especially fine cutting of metal, producing minimized roughness of the cut surface, reducing thermal effect on the work surface, or causing the least gap width. The energy of the incident beam can be controlled mainly according to the pulse duty, while varying it corresponding to the cutting speed. The pulse peak value is variable corresponding to plate thickness. If comparison is made of cutting performance between the enhanced pulse or super pulse and the normal pulse formed from the successive output, at the same average output, it allows the plate to be cut to a greater thickness. The pulsed beam serves to work efficiently when cutting sheet metal of complex shape at a relatively low cutting speed (lower than 1 m/s). However, in order to obtain a smooth cut surface, it is best to cut at a high speed, applying the successive oscillation beam.

The discharge is pulsed by the on-off operation of the alternating current silent discharge (SD) or radio frequency discharge (RF) by means of a high-frequency power source using the transistor, by the on-off operation of direct current discharge by means of high voltage electron tube, etc. The composition of the pulsed CO_2 laser is divided into the so-called transverse flow type (three-orthogonal-axes type) having three orthogonal axes, i.e., light axis, gas flow axis, and discharge axis, and into the axial flow type where the axes are in the same direction, instead of orthogonal. Details of such pulsing are beyond this article and are, therefore, omitted.

On the other hand, the TEA CO_2 laser can generate high peaked pulse of the MW class, as shown in Table 1. The laser is becoming popular for marking, for instance on electronic components where the type, model, and serial numbers are inscribed. Although this type of laser uses a high-density discharge excitation at atmospheric pressure, it can generate high sharply peaked pulse, but cannot successively oscillate. The switching operation for recurring pulse oscillation is made by means of a gap switch or thyratron. The recurring pulse of the TEA laser used for marking is below 10 pps.

In addition to its application for cutting and marking, as mentioned above, the CO_2 laser pulse control process is applied in perforating and welding. In welding, the conventional successive output type laser was mostly used. However, recently, pulse welding is being tried for the same reason for its preference in cutting the workpiece, and from the viewpoint of thermal control.

The greatest feature of YAG laser pulsing is the Q-switch. As shown in Table 1, the YAG laser machining is divided into the successive-oscillation-excited type and the pulse-excited type, in terms of its excitation methods. In the successive excitation type, the krypton arc lamp is used as its light source, while in the pulse excitation type, the xenon or krypton flash lamp is used as its light source. In either type, what is called the "giant pulse" can be obtained by means of the Q-switch operation.

The Q-switch operation is to control the Q in the resonator, that is, by quickly controlling any loss. This Q-switch type excitation method is to reduce rapidly the power loss in the resonator at the time the inverted population by lamp excitation reaches the maximum value, as shown in Figure 2(a), thereby very rapidly causing the laser to oscillate. Since accumulated energy is rapidly taken out by this excitation method, it can obtain giant pulse of sharply peaked very high pulse. There are two types of Q-switches used for different types of excitation. In the successive excitation type of YAG laser machining, the ultrasonic Q-switch is generally used, while in the pulse excitation type, Pockels Q-switch is generally used.

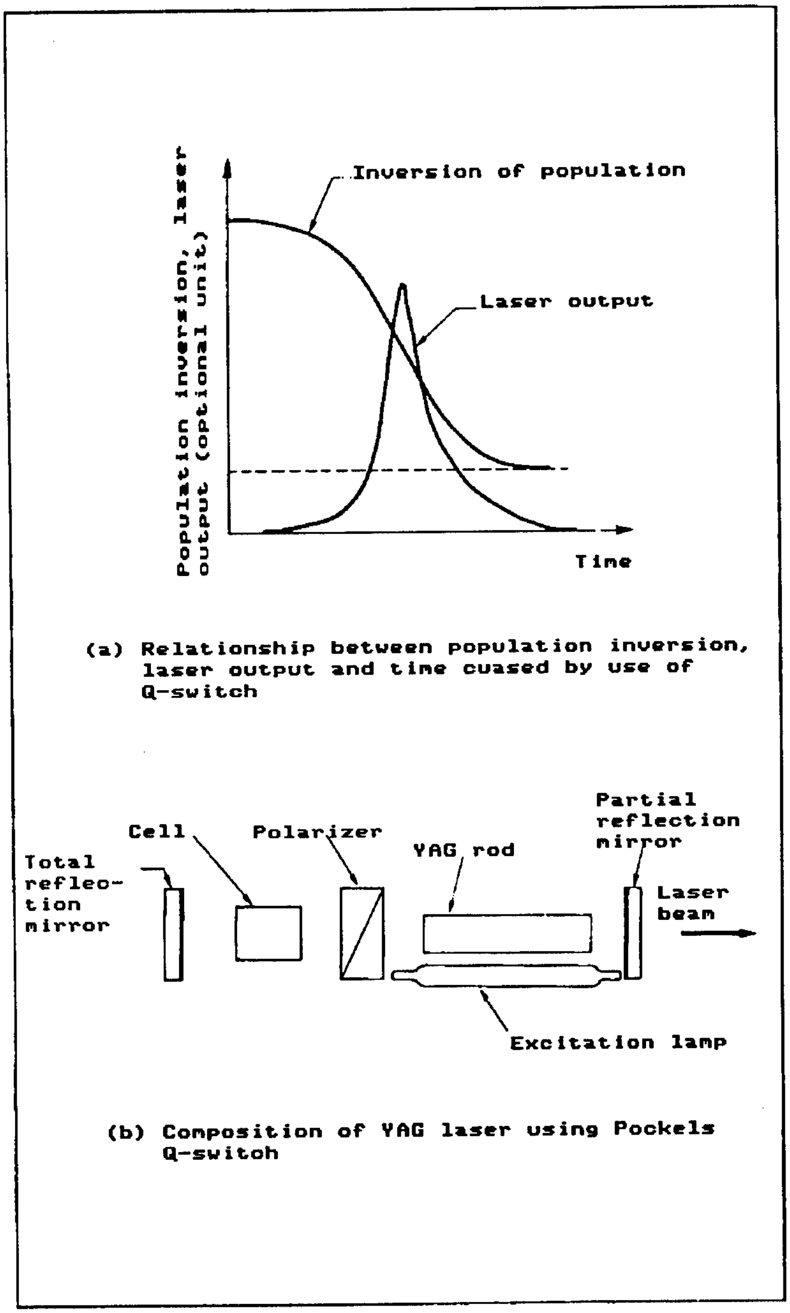

Figure 2. Q-Switching YAG Laser

The ultrasonic Q-switch method is to apply ultrasonic wave into a medium capable of propagating ultrasonic wave, and vary the refractive index for a cycle period of the wavelength of this ultrasonic wave, by means of the density-varying wave occurring in the medium, then to utilize diffractive light scattering phenomenon in the subsequent phase lattice. In other words, this method is taken for the following reason: while the ultrasonic wave is being applied into the medium, scattering loss of light is great, thus limiting laser oscillation, but when the ultrasonic wave ceases, the oscillation rises rapidly. The ultrasonic Q-switch element mostly used is molten quartz which has good optical properties and is less likely to cause damage to light. The maximum value at the sharply peaked point of the laser pulse the YAG laser generates is some 20 kw, and the value is not high. But the most important feature of the pulse this laser process generates is that it is very recurrent pulse of some 50 kHz.

Pockels Q-switching is a process using the dual refraction that generates when an electrical field is added to crystal. Namely, this pulse generation uses the optical path differential (phase differential) between the linearly polarized lightwave parallel to this electrical field and another linearly polarized lightwave orthogonal to the electric field. Figure 2(b) illustrates the structure of the Pockels Q-switching YAG laser. This method for generating YAG laser pulse by using the features of such a polarized lightwave occurring from this phase difference has the following operational features:

The impressed voltage is applied to the Pockels cell so that the above optical path difference becomes one-fourth wavelength. The linear polarized light traveling leftward generated by the polarizer, is converted to a circularly polarized light after passing the Pockels cell. This circularly polarized light reflects on the entire reflective mirror at the left, and the returning circularly polarized light passes through the Pockels cell again. Thereafter, the circularly polarized beam is converted back to the linear polarization orthogonal to the first linear polarization. At this time the beam is intercepted by the polarizer so that the laser oscillates in a suppressed state. However, at the instance the reverse numerical distribution is at its maximum, the impressed voltage cell is switched off and the laser oscillation is no longer suppressed. This immediately generates laser oscillation whereby giant pulse is attained. The Pockels Q-switching cell element is KDP crystal (potassium dihydrogen phosphate, KH_2PO_4. This Q-switching cell cannot generate such a high recurring pulse. But the most important feature of this pattern switching is that when laser oscillation is synchronized with pulse excitation of high intensity, it can generate high, sharply peaked pulse of about 10 MW.

Where Q-switching is not applied, the pulse excitation YAG laser generates normal pulse of about 0.1 to 20 ms pulse width. The recurring normal pulse resulting from such an operation is determined by the recurrence of the excitation flash lamp, and the maximum value is about 200 pps. The pulse power at the top of sharply peaked pulse is some several kw which is not very high.

In addition to the foregoing pulse oscillation, the YAG laser machining can generate up to 1 kw maximum power from continuous oscillation. Several types

of laser pulse can be selected according to machining purposes. For example, high-speed recurring pulse generated by operating ultrasonic Q-switch is used mostly for trimming, scribing, marking, etc. The sharply peaked pulse by the Pockels Q-switch operation is generally used in repairing. The normal laser pulse is mostly used in seam-welding, spot-welding, perforating, and in cutting and the continuous wave pulse is generally used in soldering and brazing.

3. Spatial Control

Temporal control together with spatial control is an important factor in controlling laser machining. Spatial control is divided into control of the transverse modes of the oscillation beam and beam pattern shaping, control of light convergence, and transmission control of beam.

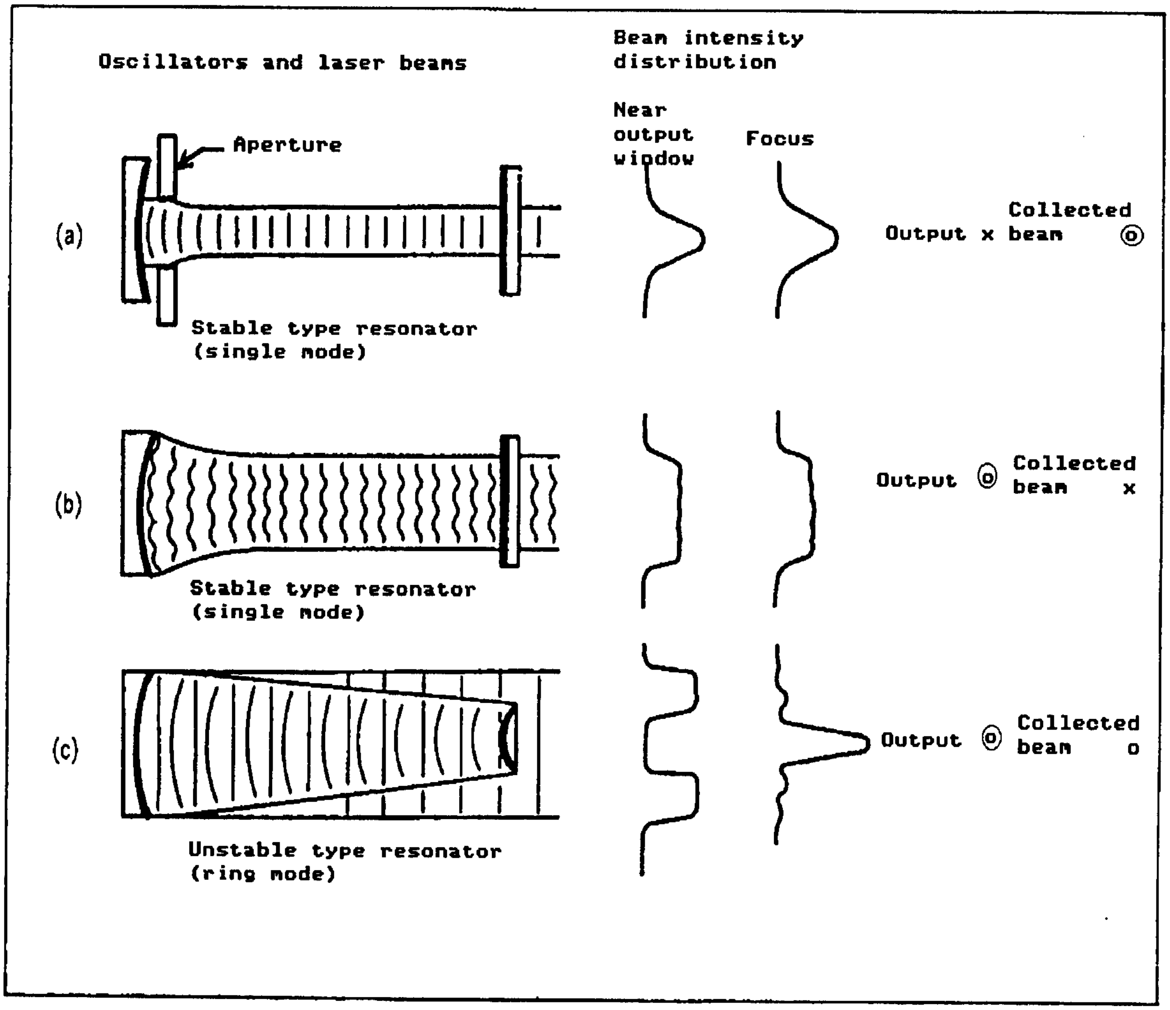

Figure 3. Types of Beam Resonators and Beam Intensity Distribution

The transverse modes of the machining laser beam are classified into single mode (TEM_{00} mode, i.e., basic mode) and multimode (TEM_{mn} model), both obtained from the stable resonator and ring mode from the unstable resonator. Table 1 shows diffusion angles of these transverse modes for the CO_2 laser and YAG

laser. Figure 3 illustrates the relationship between resonator types and beam intensity distributions.

The single mode has the best light-focusing property and is indispensable to sheet metal precision and fine machining made by using the CO_2 laser. This mode has the so-called gauss form intensity distribution. The diffusion angle is small and its light-focusing property is excellent. However, in this mode the light intensity (W/cm^2) within the resonator is extremely great. For this reason, in the case of the CO_2 laser operation, the allowable power output is limited, in view of the mirror's light-resisting strength and, in the case of the YAG laser operation, the allowable output in this mode is limited, in view of the YAG rod's thermal distortion. The maximum of the allowable single mode output for CO_2 laser is 2 kw and for YAG laser operation is from 15-20 w.

The diameter of the single mode beam can be calculated from the geometrical structure of the resonator, that is, the spacing between the two mirrors and the radius of curvature of these two mirrors. Assuming that the laser medium is uniform and there is no thermal distortion on the mirrors, the calculated and experimental values of the beam diameter agree. Consequently, in order to obtain the normal single-mode output, one or two apertures are inserted in the resonator, the aperture having an opening about 1.6 times the above beam calculated in diameter serves to suppress transverse mode oscillation of high order for the purpose of obtaining such output.

Where a pattern of beam corresponding to the size of the laser beam medium cross-section is desired, such beam can be obtained by lifting the above such oscillation restriction placed by that aperture arrangement. This is the multimode of beam. As shown in Figure 3(b), the multimode operation generates a beam of flat distribution intensity and nearly twice as much output as that of the single mode. As this mode results in high output, having a low light-gathering property, it cannot be used for cutting, but can be used for welding, surface reforming, or for removal machining, such as trimming and marking. The CO_2 laser generates 2-5 kw, and the YAG laser 20 w to 1 kw multimode output. Although referred to as multimode, there is a difference in quality of beams. That is, the low-order multimode CO_2 laser beam of diffusion angle of 2-3 mrad is usable also for deep fuse-in welding or thick plate cutting where the thermally affected layer is small. Then, the high-order multimode beam is suitable for surface reform treatment, such as case-hardening due to its flat distribution of beam intensity.

The desired degree of the multimode beam output order can be obtained by varying the diameter of the aperture inserted in the resonator. Furthermore, the shape of the beam pattern can be altered by varying the shape of the aperture. For example, by using the circular aperture, an axis-symmetric beam pattern of multimode is obtainable, and by using the rectangular aperture, a square pattern beam of longitudinal and lateral mode orders can be obtained. Such variation of the beam shape by the above method is possible, due to the altered aperture shapes having corresponding light-diffraction effects resulting in such varied shapes of beam patterns.

In operating the 5-20 kw class CO_2 laser, the output is extracted from the unstable type resonator. The unstable type resonator can extract superior

quality of high-beam output from a large space section of discharge. As shown in Figure 3(c), this resonator is composed of two metallic mirrors, concave and convex. This unstable type resonator extracts the beam output by the process that the convex mirror makes the beam diffuse, the concave mirror subsequently transforms this diffused beam into parallel beam, then the beam projecting out of the periphery is extracted as the output power. Thus, the beam obtainable by this method using this type of resonator is of the ring-shaped mode. This method, for outputting high power ring mode beam, is devised so that the output beam is a flat wave, normally using selected radius of curvature for the concave and convex mirrors. Therefore, the ring-mode beam obtained by this method has a small angle of diffusion and an excellent light-gathering property. The laser beam generated in this way is quite suitable for thick plate cutting and fuse-in welding. However, for surface reform treatment, it is not usable, unless its characteristics are modified. That is, this mode beam needs to flatten the beam intensity distribution.

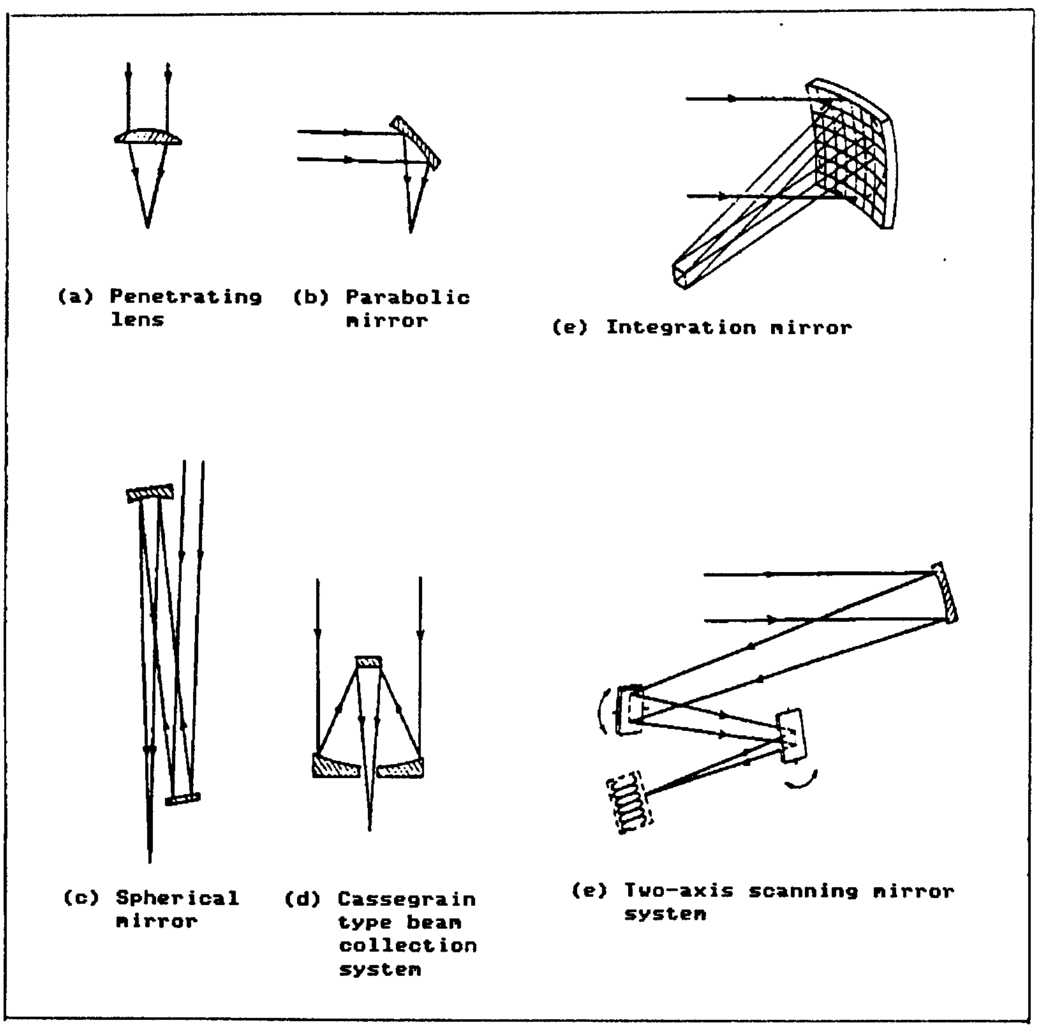

Figure 4. Machining Laser Beam Collection and Shaping Optics System

Along with the technology of improving laser beam quality, technology regarding light-beam gathering capacity and beam reshaping function is important for laser beam machining generation. Several different schemes of light-beam gathering and reshaping are adopted according to machining purposes, output, and the mode required. Figure 4 shows different optical systems of light-gathering and shaping for laser beam machining. The typical system for gathering light is the penetration lens. In addition, the reflective parabolic mirror, spherical mirror, Cassegrain type optical system are used. In the case where a large output beam is intended to be obtained, the reflective type group of light-gathering systems is mostly used, instead of the penetration lens which, in such a case, is not usable because of its light-resisting strength.

The parabolic mirror system has the advantage of allowing a greater work distance, that is, the mirror may be placed at a greater distance from the work to be machined. Consequently, the mirror becomes capable of performing action with a small aberration. Its drawback is that fabrication and light-axis adjustment are difficult and costly. The spherical mirror method needs a plane mirror for establishing a smaller angle of incidence to make less aberration. This has its disadvantages in that the work distance is unavoidably smaller due to placement of the plane mirror. The Cassegrain form of the optical system is used for light-gathering to generate the ring mode beam. This form has an advantage of allowing a greater workpiece distance and a shorter effective focal distance. But in this form, the light beam is used at a low rate of energy because the beam is partly intercepted by the mirror holder.

As described above, to apply the laser beam to a surface reform treatment, technology for flattening the beam intensity distribution is indispensable. The integration form system emits a beam of flat intensity distribution. The integration mirror is composed of many dice-like plane mirrors bonded to a spherical substrate, and it produces beam of flat intensity distribution by multidividing and overlapping the beam. The two-axial mirror scanning method adopted in CO_2 laser machining using a wider-angle metallic mirror is not practical, because the scanning frequency is confirmed to 200 Hz at the most, by the mirror holder inertia. It is further impractical because uniform heating cannot occur. Conversely, such a scanning method is used in many cases for marking, etc. in YAG laser machining because high-speed scanning is possible in that type of laser. For achieving flat distribution of beam intensity, other methods are being tried, including one using the kaleidoscope.

Another important issue for laser beam spacial control is the control technology of beam propagation and direction. In the large output CO_2 laser machining system, it is very important to transmit the beam without degenerating beam quality, the optical path in this system is as long as some 20 m. Particularly in the case where the flat wave obtained from the unstable resonator is to be used, a transmission optics system and the light-gathering optics system must be designed taking into consideration the fact that light wave condition is variable depending on the distance of optical transmission. Thus, designing the transmission optics system based on Fresnel refraction is necessary. Furthermore, change in the refraction index (thermal blooming)

or light-swaying resulting from light absorption into the transmission air space has considerable undesirable effects on light-beam gathering characteristics. Thus, light absorption control is needed. The method normally taken for such control is that nitrogen, or another appropriate gas that will not absorb light of 10.6 μm wavelength, is continuously circulated in the light transmission path and cut off from the surrounding atmosphere.

Concerning the transmission optics system for the YAG laser machining, it is worthy of special mention that optical fiber is applicable in such a system. Unlike the mirror system, in which beam direction control is difficult to control and liable to cause beam instability and attenuation of output, optical fiber is flexible and serves to vary beam direction. This can greatly increase the degree of freedom in designing the transmission optics system. Consequently, this makes it possible to constitute the structure for performing concurrent machining at multiple points or time-sharing machining by switching the beam incident on the optical fiber. Nevertheless, YAG laser beam obtained from the projection system using optical fiber has a degraded beam characteristic in respect to the beam spot diameter. After passing the optical fiber, the beam is led to the workpiece by the image-forming optical system. The collected-light spot diameter is determined by the optical core fiber diameter and enlargement rate given by the light projection system.

In the optical fiber method, the beam can only be compressed to the extent that the resultant collected-beam spot is 0.2 to 0.3 mm in diameter. This is because the laser beam, after passing the optical fiber, loses incoherence. This means substantial degradation of the beam characteristic occurring in the operation using the optical fiber, as compared with the YAG laser beam some 10 μm in diameter obtained in the normal method of operation.

4. Beam Polarization Control

As is mentioned in the introduction, in addition to thermal control which includes temporal and spatial control, light-beam polarization control, expressed as controlling energy absorption in the workpiece, is an important technology in laser machining, particularly in cutting with the CO_2 laser. A typical function of cutting with the CO_2 laser is to severe sheet metal in a desired shape with CNC. To achieve what is called the "fine cutting" means obtaining a good cutting quality including uniformity of cutting width, severed surface smoothness, thermally affected layer, etc. No matter how accurately the energy of the incident beam is controlled, if the energy being absorbed in the work has directional dependence, it is not possible to severe with uniform cutting quality. As is well known, the energy absorption characteristic for metal has polarized-light-dependence. If the CO_2 laser has no anisotropic polarization optics element like Brewster window within its resonator, it normally emits oscillation output having elliptically polarized light wave. The direction of its long axis varies. Accordingly, if sheet metal is severed by use of such a laser beam, the cutting quality would involve directional dependence and quality reproducibility would be poor. For this reason, in the metal cutting machine, the circular beam polarization optics system is generally used (Figure 5).

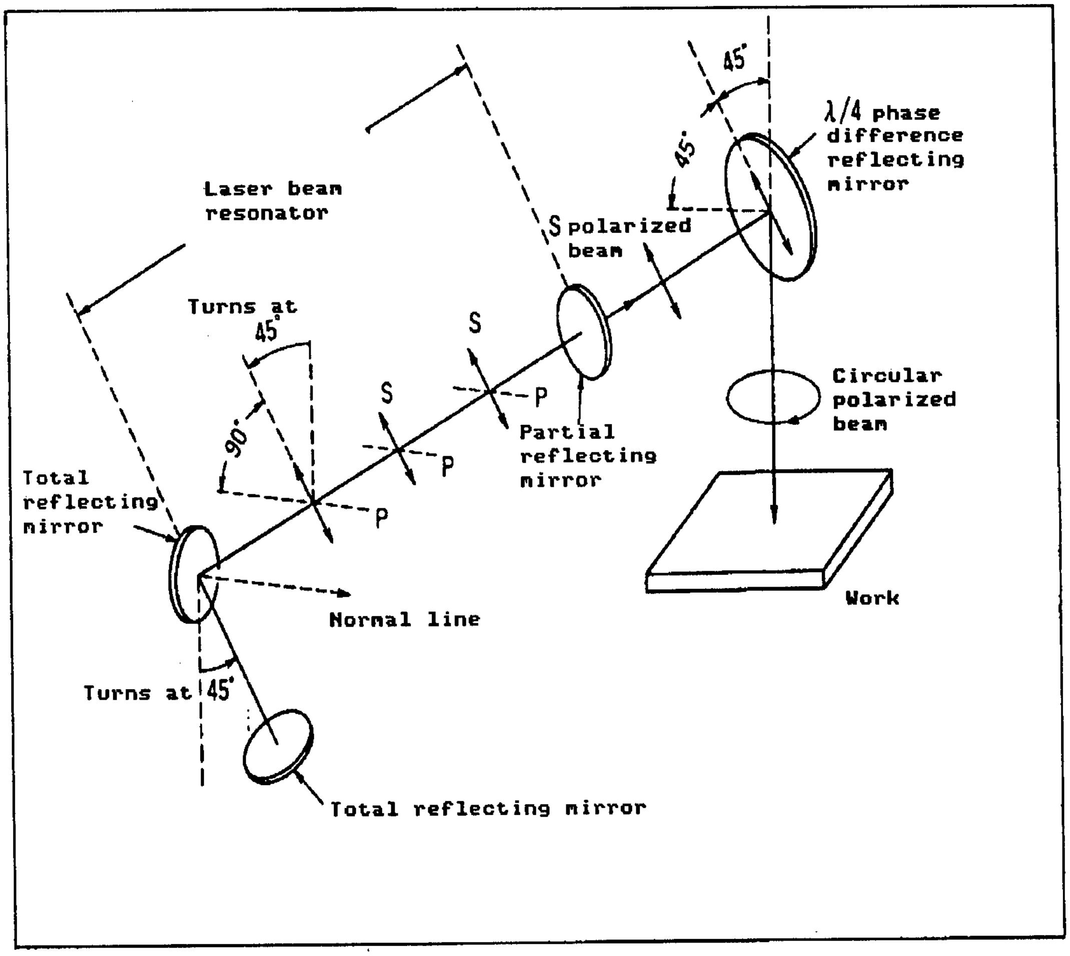

Figure 5. Schematic View of Optics System for Generating CO_2 Laser Circular Polarized Beam

Within the laser resonator of the above optics system, the totally reflective mirrors of 45° angle of incidence are placed as the anisotropic polarizing device. The operation of such a circular polarization optics system is to oscillate polarized light beam "S" (polarized beam component perpendicular to the principal plane) selectively, then to transform only this component to the circularly polarized beam, by means of the one-fourth-wavelength phase-difference reflective mirror, and guide it to the workpiece.

At present, this schematic of beam polarization control is needed only in metal cutting in which the initial absorption of energy greatly affects the cutting quality. But such a schematic is not presently a consideration in metal welding in which linear beam operation is mostly needed.

5. Conclusion

In thermal machining by using the CO_2 laser or YAG laser, machining quality is determined, depending on the performance of thermal control. From this standpoint, thermal control of the laser beam mainly for the CO_2 laser has

been described in this article, dealing with temporal, spacial, and beam polarization control. Also important for laser machining are the techniques of guiding the beam to the desired position, without rendering degradation, and of converting the beam to appropriate patterns for various machining purposes. These techniques have been described in this article.

In the future, it is believed that laser machining will develop to minute machining such as through excimer laser chemical machining or a new form of solid-state or high-frequency laser. This technology will be discussed at another time.

BIBLIOGRAPHY

1. Nagai, "Laser Machining Technology," JOURNAL OF THE INSTITUTE OF ELECTRONICS AND COMMUNICATIONS ENGINEERS OF JAPAN, Vol 68 No 4, 1985, p 482.

2. Nagai, "Structure and Characteristics of CO_2 Laser Oscillator and Problems," Laser Machining, Laser Technology Data Collection, Management System Research Institute, Inc., 1984, p 35.

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JOYO MARKS 10TH ANNIVERSARY

Tokyo ENERUGI FORAMU in Japanese Jun 87 pp 129-131

[Article: "Total Operation Time, 28,000 Hours"; first paragraph is editorial introduction]

[Excerpt] Joyo Achieves 10-Year Record

The fast experimental reactor, Joyo, which reached its criticality in April 1977, has provided valuable experimental and research data to the prototype reactor, Monju, which is presently being constructed. After construction of the Monju is completed, basic research work for the next demonstration reactors will be performed in both the Joyo and the Monju. The Joyo has brought about a firm conviction that development in this field is practical and will continue to develop toward becoming a popular nuclear reactor.

Huge Project of Original Technologies

FBRs (fast breeder reactors) are called the ideal nuclear reactors because, compared with conventional LWRs (light water reactors), valuable uranium can effectively be used several tens of times. Research and development of this type of reactor is being accomplished worldwide. In Japan, Joyo has been continuing to operate smoothly since it was constructed in the Oarai Engineering Center of the PNC (Power Reactor and Nuclear Fuel Development Corp.) and reached its first criticality on 24 April 1977.

10-Year Achievements of Joyo

The Joyo has attained a total operating time of 28,000 hours and an integrated output (thermal output) of 2.3 billion kw. It has been operating stably without any leakage of sodium from cooling materials, damage of fuel rods, etc., since its first criticality in 1977.

Also, Joyo has been subjected to six periodic inspections since its first inspection in 1979, and maintenance technologies for FBR have been developed. Data on operation, maintenance, and malfunction histories of Joyo's approximately 5,000 main equipment parts are registered in the fast reactor equipment reliability database. Its reliability is evaluated on the basis of the results of these data, and are reflected on the maintenance plans of Monju. The total sodium traveling distance in the primary and secondary

cooling systems is approximately 1.1 million km, which is equivalent to one and one-half round-trips from the earth to the moon.

During this period there were about 550 reports relating to tests published in book form, broken down as follows: 150 reports on operating characteristics, 130 reports on special tests, 100 reports on reactor core, 80 reports on plants, 50 reports on instrumentation, and 40 reports in other categories. It can be said that these reports completely cover all areas of the FBR.

In addition, Joyo has radiated a total of 33,033 fuel elements of radiation fuel and reactor core fuel, and has reached the highest burnup of 70,000 MW-days per ton for 10 years since its first criticality. Valuable knowledge concerning behavioral characteristics of the irradiated FBR fuel and materials has been obtained by performing post-irradiation tests on about 4,000 of the fuel elements.

During this 10-year period, an FBR nuclear fuel cycle has been demonstrated, and testing, etc. for observing fuel behavior has been performed on-line. After the fuel irradiated by the Joyo is reprocessed, this FBR nuclear fuel cycle enables the fuel to be reused in the form of a fuel pellet.

Challenge to Innovative Technologies

In order to practically use FBRs they must be able to economically competitive with LWRs. The reduction of fuel cycle costs can be cited as necessary research in this area. In order to achieve this, it is necessary to improve the present fuel performance further. In the Joyo, the safety tolerance of fuel is being reviewed, detecting problems and points of improvement to increase the performance, and a low swelling fuel cladding tube is being developed giving consideration to these issues.

Research on the use of AI (artificial intelligence) has long been carried out. Operation-maintenance support systems are being developed to increase reliability of fast reactor operation and for work efficiency. Research and development of AI application is a main focus.

Also, assurance of a means of removing decay heat generated from natural environments can be expected, because sodium is used as a coolant in FBR, even if natural environmental force is generated by the configuration differences between the reactor core and the cooling equipment and by the density difference due to the sodium temperature difference, and even if forced-circulation cannot be performed by pumps due to total power source loss. With regard to the capacity of the Joyo, it was confirmed that the Joyo can sufficiently remove decay heat generated after output scram of 100 MW.

In addition, the development of on-line irradiating technologies is being carried out in the Joyo. When the INTA-1, the first instrumentation wired assembly, was completed in December 1986, the irradiation to this assembly was already finished. Irradiation tests by means of the INTA-2 having a simplified structure are being planned aimed at further increasing measuring accuracy on the basis of results obtained.

Overall Research on Practical Use of FBRs

An idea for a secondary system removal plant has been proposed as one of the new concepts for promoting the practical use of FBRs with a view toward reducing construction costs. The use of a secondary removal plant using a double tube SG [steam generator] has been considered, and R&D of this plant is being carried out in order to make it practicable. At present, the modification and study of installing such a double tube SG in the secondary removal plant of the Joyo is progressing on the assumption that the Joyo will be fully utilized as a demonstration reactor for establishing this secondary removal plant.

In addition, research on new materials is being conducted in the Joyo. For example, the Oarai Engineering Center is developing the CP [condensation pump] trap using nickel, cobalt-free alloy which replaces CP cobalt surface curing agents, and the fractional curing type ferrite steel as a low swelling fuel cladding material.

Also, aseismatic research is being conducted as another important area so that the secondary removal plant can be constructed on the quaternary stratum site.

Nuclear power plants based on the present aseismatic design are constructed on the tertiary era ground, but it is forecast that it will become difficult to ensure construction sites which will meet these conditions in the 2000's. The Oarai Engineering Center is conducting experimental research on Joyo in collaboration with CRIEPI [Central Research Institute of Electrical Power Industry] for the purpose of establishing an aseismatic designing method of underground objects and for experimentally demonstrating that if these underground objects are buried deeply even in the quaternary deposit ground as a part of the measures for location, they will exercise their excellent aseismatic properties.

The Oarai Engineering Center where the Joyo stands is located along Route 50 facing the Pacific. Six hundred staff members and 500 outsiders regularly come and go to this extensive spacious site of 180,000 m^2.

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JAEC'S URANIUM ENRICHMENT REPORT DISCUSSED

Tokyo PUROMETEUSU in Japanese Jan 87 pp 86-87

[Article by the Nuclear Fuel Section of the Atomic Energy Bureau, Science and Technology Agency: "Report by the Uranium Enrichment Committee of the JAEC"]

[Text] 1. Preface

On the threshold of the 21st century, the Uranium Enrichment Committee of the Atomic Energy Commission of Japan (JAEC) was organized in December 1985 in order to survey and deliberate on the development of future uranium enrichment and the course of its technological development. The committee has deliberated seven times since its inception.

This report was compiled based on the details of a report by the Laser Process Technology Working Group organized under the committee in order to hold intense discussions on enrichment technology the by laser process. The following is a summary of this report.

2. Situations Concerning the Nation's Uranium Enrichment

Based on the results of development of the centrifugal separation method, primarily by the Power Reactor and Nuclear Fuel Development Corp. (PRNFDC), a prototype plant based on that method was constructed. With the Japan Nuclear Fuel Industries Co., Inc. (JNFIC) as the prime commercial plant enterprise, and the Uranium Enrichment Equipment Co., as the manufacturer of centrifugal separators, and others being established, a system for commercialization of the nation's uranium enrichment technology has been steadily arranged for more than 20 years. A plan for constructing a 1,500-tSWU/year final-scale capacity commercial plant at Rokkasho village, Aomori Prefecture, is smoothly proceeding. With the excessive capacity of uranium enrichment service in the background, a fierce price competition is taking place globally. In June 1986, the United States announced a new project strategy aimed at the immediate streamlining operation of the existing gas diffusion plant and the promotion of development and proving of the atomic power process. Also, France, West Germany, and at Urenco, etc., will promote the development of new technologies. Therefore, the situation surrounding uranium enrichment assumes a complex aspect.

3. Significance of Establishment of Uranium Enrichment Project and Future Basic Policy

The significance of proceeding with domestic production of enriched uranium in Japan has remained unchanged even today from the standpoints of assurance of stable energy supply and also in the establishment of a spontaneous nuclear fuel cycle. In the following phases of the enrichment project development such as strengthening industrial foundation, ripple effects of technology, and effective control of enrichment service price on the international market cannot be disregarded.

Therefore, it is expected, first of all, that the enrichment project will start up on a minimum required scale and, subsequently, on establishing an systematic linking of efforts for reducing cost and expansion of the project. Expanding the scale of the enrichment project to 3,000 tSWU/year by the year 2000 can be considered an index of immediate establishment. Also, most important is that new technology should properly be introduced to increase economy.

4. Future Technological Development Strategy

Upgrading of Uranium Enrichment Technology by Centrifugal Separation Method

The existing centrifugal equipment must be proven in the block test scale and pilot test scale in the future. However, the prospect is that the machine can be technically commercialized.

From now on, the government should collaborate with the private sector, properly arrange their organization, and accelerate and promote technological development to complete proving of the block test scale and the corresponding development of mass-production technology, possibly in 1990. Then an appropriate check and review of developmental results along with a study of the technological development plan should be made at the opportune time.

Strengthening Uranium Enrichment Technological Development by Laser Process

In this country this technology is at the fundamental stage. Therefore, the results of future development must be awaited.

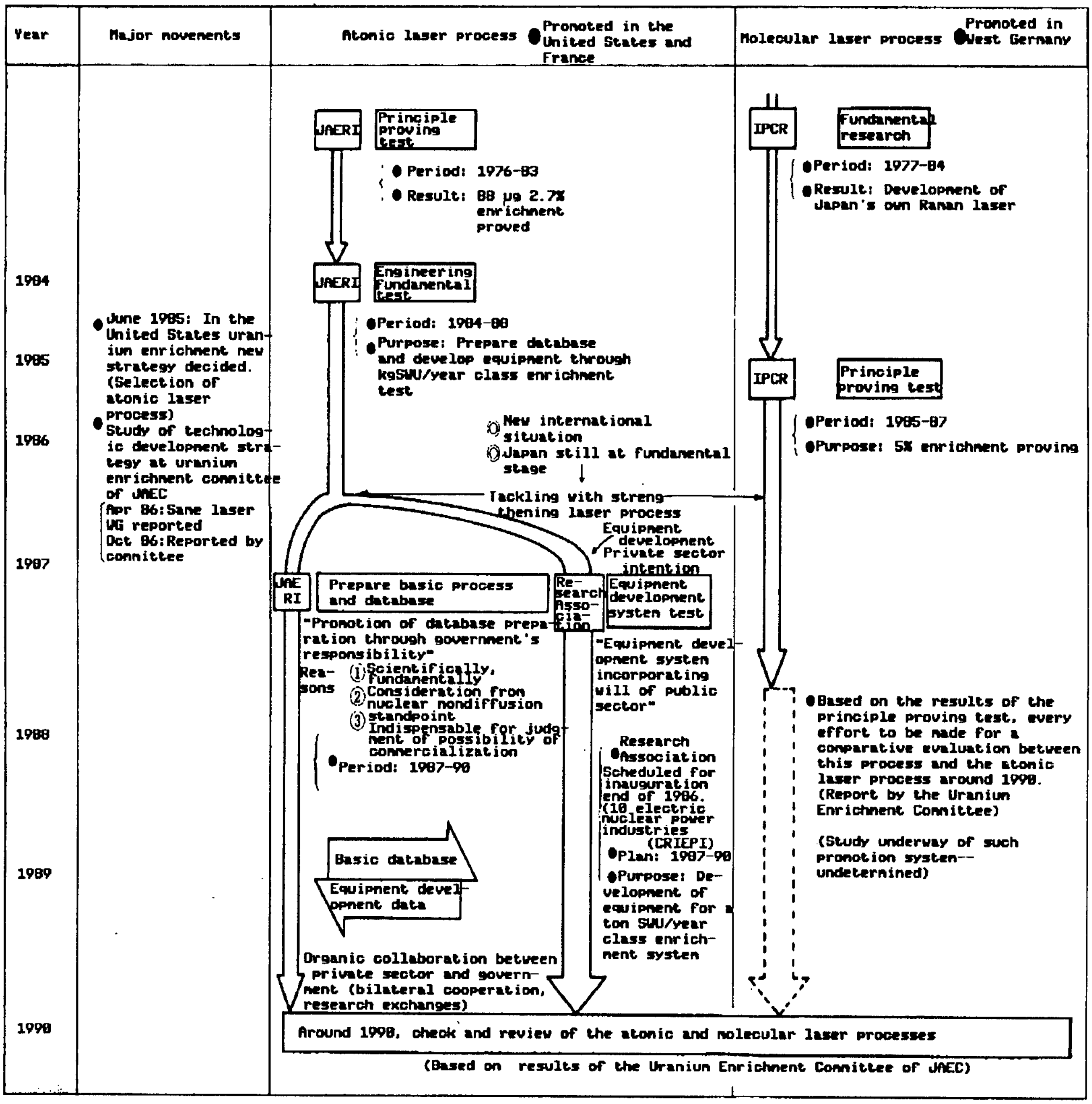
For the following reasons, however, strengthening development strategies is necessary.

1) Possession of low-cost technology for maintaining long-range international competitiveness

2) Viewpoint of responsibility as one of the major nuclear power developing countries, and also technological national security

3) Expectation for effects of the advanced technology factors in the laser process in other areas.

Consequently, the immediate definite policy to be implemented by around FY 1990 is as follows:



Course of Uranium Enrichment Technological Development by Laser Process

1) Regarding the atomic process the role of the Japan Atomic Energy Research Institute (JAERI) is to establish collecting and regulating database regarding the fundamental process indispensable for making systematic engineering and economic evaluations of a system by such process, and make every effort to clarify the principle of the process.

Meanwhile, in order to achieve developmental issues as soon as possible, the role of the private sector is to be responsible for developing equipment and conducting a test on the enrichment system of a scale of a ton SWU/year under

the research association system and also detecting and studying problems up to commercialization of the process. The private sector will start on the study of the reenrichment of recovered uranium by the atomic process.

2) Regarding the molecular process, the Institute of Physical and Chemical Research (IPCR) will complete the principle proving test with the PRNFDC's cooperation and every effort will be made to make a comparative evaluation with the atomic process based on the results of the test. Furthermore IPCR will study the future promotion of the system.

3) In addition, in developing the laser process, the concentration of wideranging technological capabilities over a long period of time is not only indispensable, but giving consideration to nuclear nondiffusion is also important as well. Therefore, it is necessary to establish a setup for proving the evaluation and adjustment of development, under JAEC.

Continuation of Uranium Enrichment Technology Development by Chemical Process

The development of this process has been progressing in the private sector. During this period, the exchange performance of adsorptive materials, etc., made technological progress. Presently, the private sector is preparing a test, using the model plant, in order to attain commercialization technology. For the future, it is necessary to make a timely evaluation of the results of that test.

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5-YEAR PLAN FOR GEOLOGIC DISPOSAL DEVELOPMENT

Tokyo PUROMETEUSU in Japanese Jan 87 pp 82-83

[Article by policy planning official of the Atomic Energy Bureau, Science and Technology Agency: "5-Year Plan for Geologic Disposal Research and Development"]

[Text] Purpose of and Background for "5-Year Plan"

At the Japan Atomic Energy Commission (JAEC), it has been decided that the following developmental steps will be taken regarding the geologic disposal of high-level radioactive wastes, based on the past results of "Selection of the Effective Bed" (first step).

(1) Selection of the proposed disposal site (second step).

(2) Proving of disposal technology at proposed disposal site (third step).

(3) Construction and operation of the disposal site (fourth step).

Before proceeding in the second step: 1) studies on available literature, estimates, and boring surveys will be conducted nationwide; and 2) the necessary research and development will be promoted along with these studies in order to select the proposed disposal site.

Also, the JAEC is mapping out its annual plan for proceeding with safety research on the geologic disposal of high-level radioactive wastes.

Based on such policies, the JAEC and the Nuclear Safety Commission, the Atomic Bureau of the Science and Technology Agency, has summarized such specific issues for the promotion of R&D by the government and also the sharing of responsibilities among the organization concerned during the upcoming 5 years (1987-1991) which almost equals the first half of the second step, as "5-Year Plan for Geologic Disposal Research and Development."

Consulting the opinions of experienced scholars, its purpose was to further smooth promotion of R&D as mentioned above as the nation's important project.

2. Summary of "5-Year Plan"

(1) The 5-year plan generally shows methods for promoting R&D at the second step as follows:

1) In order to establish the necessary technological basis for selection of a proposed disposal site at the end of the second step and accumulate scientific expertise, the development of the geologic disposal system, testing and research on safety evaluation of the geologic disposal, etc., will be promoted overall.

2) With a view to accurately and efficiently conduct surveys for selection of the proposed disposal site, the development of and improvement in survey technology for site characteristics will be attempted.

3) In the third step, a survey tunnel will be excavated at the proposed disposal site selected at the second step and by conducting various tests to verify radwaste disposal technologies. Accordingly, R&D will take place in preparation for shifting into the third step.

(2) Based on the general methods for promoting R&D of the foregoing second step in the 5-Year Plan, the following are enumerated as important items:

1) Research survey on the geologic structure and hydraulic mechanism of the nation's soil bed will be made to grasp geologic environmental conditions. At the same time, development of the artificial barrier system according to such conditions will be promoted and the conceptual design (design at the stage where specific location of disposal site is not undetermined) of the geologic disposal system devised based on the results. Consequently, the basic specifications of the nation's geologic disposal system will become clarified.

2) The fundamental concept of the long-range reliability of the geologic disposal system will be formulated.

3) In order to establish data on safety and reliability of geologic disposal, original position tests will be promoted using, for instance, the actual rock bed of the existing mine.

4) In the latter half of the second step, the R&D results currently available will be assembled, and large-scale research facilities (environmental engineering test facilities and deep bed test site) will be constructed in order to promote overall R&D in geologic disposal.

5) Surveying technology will be developed for site characteristics in order to evaluate accurately and effectively the deep geologic environment without greatly affecting the geologic environment of the survey point.

6) Detect similar natural phenomena useful for evaluating segregating function of an artificial barrier and also for the segregation function and long-range stabilization of a natural barrier, and conduct survey and research (natural analog research) thereof.

7) Basic database regarding geologic disposal (such as thermodynamic data regarding nuclide shifting within artificial and natural barriers, and the nation's geologic environmental data) will be prepared.

8) Promotion of international cooperation.

(3) In the 5-year plan the following shows the share of responsibility for each organization concerned.

1) The role of the government.

The government will take necessary measures so that R&D in the geologic disposal will appropriately and definitely progress.

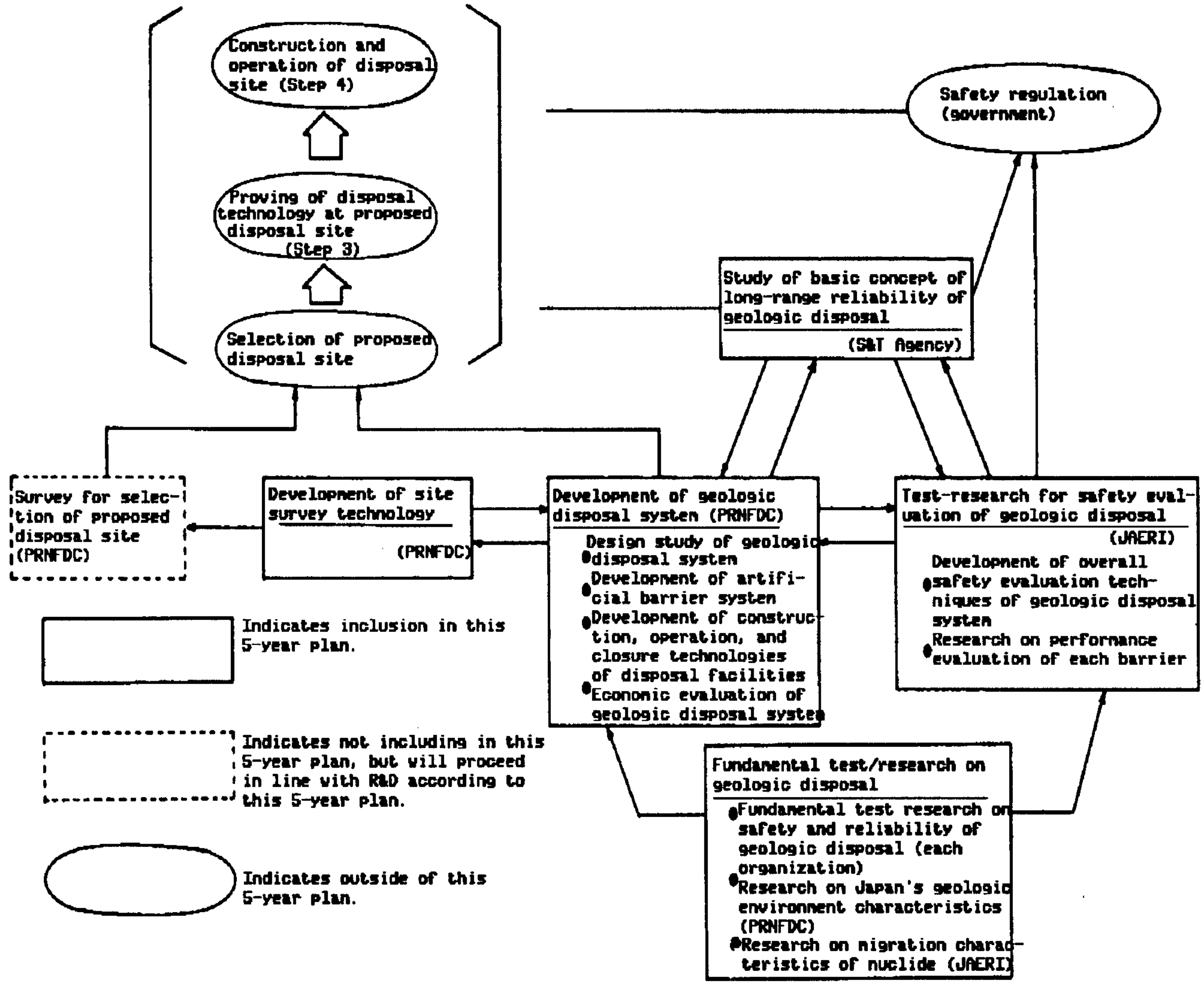
In particular, the government will regularly evaluate the status and results, etc. of the R&D of each organization, and will make an overall adjustment of R&D based on the evaluation results.

2) As the core organization of the developmental project of geologic disposal, the Power Reactor and Nuclear Fuel Development Corp. (PRNFDC) will promote R&D aimed toward establishing the nation's geologic disposal technology, in parallel with the nationwide survey for the selection of a proposed disposal site.

3) Maintaining close collaboration with the PRNFDC involved in the developmental project, Japan Atomic Energy Research Institute will be responsible for promoting research contributing to the government's safety evaluation of the geologic disposal together with conducting fundamental research by regulating database pertaining to nuclide migration, etc. Also, JAERI will conduct research on future technology and new technology from a long-range viewpoint.

4) National test and research organizations, such as the Geological Survey Office and the National Research Center for Disaster Prevention, will conduct research by making the most of the respective expertise fields, maintaining collaboration with the PRNFDC and JAERI.

5) Each of the above R&D organizations shall establish close contacts with the private sector and universities involved in research activities. In particular, the PRNFDC will obtain the cooperation of the private sector, such as the electrical enterprises, mining companies, civil and construction companies, etc. and proceed with the developmental project while completely utilizing their technological capabilities.



Relationships Between R&D Issues

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TOSHIBA'S INVOLVEMENT IN BUILDING SOVIET AIRCRAFT CARRIER WITNESSED

Tokyo BUNGEI SHUNJU in Japanese Sep 87 pp 148-162

[Article by Hitori Kumagai, former director of the Moscow Office of Wako Koeki: "The Toshiba Case: Accusations of a Key Player (The Second Charge); The Soviet Aircraft Carrier the West Is Building; 'The West' Is Building a Soviet Aircraft Carrier. I Witnessed It at the Baltic Shipyard!"]

[Text] When Peter the Great decided to build a city at the Neva River delta in the beginning of the 18th century, it was a swamp land in the wild.

The foresight of Peter the Great to build a city on this land as a "window to the West" is historical fact. The truth is that the shipbuilding industry sprung suddenly [on its own] on this land. However, if the truth be told, this land is inappropriate for building heavy items such as ships.

At present flooding is still a source of distress for Leningrad. When flooding is severe, the water table rises close to 2 meters, the streets become flooded, and old Leningrad comes to resemble Venice. At present an enormous project is steadily underway to attempt to somehow or other subjugate this flood known as "Nawadoneshinie [transliteration]." The project consists of building a huge levee in the Gulf of Finland to prevent the high tide from coming in and displacing the water from the Neva River outside the levee by a powerful pump. The construction of the levee of this grand project has already begun and is making progress steadily.

The "Toshiba affair," which has created a sensation in the news over the past 3 months, has reached the zenith here. My accusations have turned into a problem shaking both Japan and the United States, not to mention Toshiba, but the course of events has gone off in a different direction than I intended. My memoir in last month's issue was an attempt to portray the facts accurately and not to prove that one company, Toshiba, has committed a COCOM violation or that the individual arrested should be blamed. I do not mean to be self-righteous, but I did not consider this to be a "Japan bashing" problem, but a free world problem. Somehow the public does not seem to understand that. Consequently, I would like to recount the situation in further detail.

Many-storied buildings built on top of marsh lands exist in mysterious fables of the past, but are unsuitable for modern day industry which demands exact precision.

There are methods for supporting the 10-story buildings that make up the majority of the buildings of this city, but the city's foundation is too weak to support the installation of heavy machines that would add a weight of several tons per square unit and could not guarantee the required precision.

At first, the heavy equipment might appear stable if a pit was dug 10 meters deep, a large volume of cobblestones was thrown in, and the foundation stone was firmed up by strong cement before installation, but within a week the foundation would shake. What would be even more troublesome is if the sea water moved through streams underneath the earth, turned into a flood, and resulted in an increase in the rise of the tide, the foundation would begin to rise somewhat. Should the foundation rise several millimeters, precision machinery could not be used. When the water receded, the foundation would be "thin," and the precision would be warped.

The soft delta ground is inappropriate for the installation of precision machinery, but when geographic conditions are taken into account, Leningrad is a most appropriate city for shipbuilding. It sits in the geopolitical center of the four fleets of the Soviet Navy: the North Sea Fleet, the Black Sea Fleet, the Baltic Fleet, and the Pacific Fleet.

Consequently, on this soil resides a Soviet military plant of proud lineage: the Baltic Shipyard, which is the problem at hand.

The Baltic Shipyard

At the front gate of a factory installed on a low roof is an electric sign post that displays both temperature and time and reads "Sergo Orzhenikize Memorial Baltic Factory." One would in no way imagine that this is the military plant in charge of the construction of the Soviet fleet. A street car linking Vassily Island, where this factory is located, and the heart of Leningrad runs in front of the front gate. The interior of the shipyard can be seen faintly through the front gate from the street car tracks, and there is a square where the picture of meritorious workers adorns a board called the "Placard of Honor." In the background, the machine processing division building stands in the way and blocks one's field of vision.

A Soviet factory is probably like factories everywhere, but three or four female uniformed security guards armed with pistols are always on duty at the front gate and closely check the factory workers and visitors entering and exiting. On the floor of the small booths for the security guards is a devise from which a steel bar protrudes to obstruct suspicious persons. The petal of this device is always kept down by the guard's foot. If the

guard should move her foot, the steel bar will spring up and block the suspicious party. Even if the guard is killed and the intruder gets through, means have been implemented for defensive measures to be taken automatically. When foreigners like us pass through here, we must always be accompanied by a responsible party from the Soviet side. The Soviet party must record beforehand the number and names of the foreigners and the times they enter and exit the factory. If the name of the Soviet party does not match with his identification card, trouble will ensue. Foreigners cannot go through the plant unescorted for whatever reason. Even the plant's officials must present their identification cards whenever they pass into or out of the plant. One often comes across the scene of an official jokingly asking a female security guard whom he knows for a date but still needing to present his identification card before being let into the plant as soon as that is done.

The milling machines of Toshiba Machine were installed in a separate factory belonging to the Baltic Shipyard on the opposite side of the streetcar line across from the main plant. The site is split by the streetcar line but is part of the main plant. Although the propellor factory has a security system similar to the main plant's, security there was considerably looser.

The propeller factory is split mainly into a casting section and a machine processing section with an administrative area in addition. The machine processing section is further divided into two areas. One area is full of Soviet-made machines. The other, which is secluded and separated by a wall, consists exclusively of imports from foreign countries. The area of both is probably around 2,000 tsubo [about 8,000 square yards]. A 50-ton crane travels overhead on the ceiling, and this section is linked with the casting factory and with the main Baltic plant by truck. A special track connects this plant with the main railway station in Leningrad.

The waiting room for foreigners is in a 3-story administrative building across from the main entrance and is a room about 10 tsubo [40 yards] square in the upper righthand corner of the building. One can barely see from there an apartment building and backyard on the other side of a brick wall, and one cannot see any of the plant facilities. A computer room to process the data necessary to make propellers is located in a 5-story building opposite our waiting room in the administrative area. The entrance to this room is closely controlled.

Factory Boss Firusukov [transliteration] notified us on the first day of work that taking pictures inside the propeller processing factory and entering areas other than those designated inside the factory without permission were forbidden.

We were also prohibited from making telephone calls from within the factory to the Port Hotel, where we were staying, or to the Wako Koeki Moscow branch office.

It was out of the question to attempt to make an international call to Japan from a telephone in Firusukov's office. When it was necessary to urgently contact the headquarters of Toshiba Machine about work, I had to return immediately to my hotel and place an international call from my room. Moreover, I had to ask the permission of the security guards for an escort in order to leave the factory.

I was not allowed to use the toilet that the Soviet workers used on the factory floor. Each time I had to climb a long flight of stairs to a toilet near the waiting room.

Our 10-tsubo room was neatly arranged with tables, chairs, lockers, cupboards, an icebox, and even a teapot. So, we surmised that we were being treated extremely well as far as a Soviet factory was concerned.

Russian Chaos

In the early spring, the Staryy Bolshevik, a Soviet ship, left Tokyo Bay and took a roundabout way home through the Bering Strait and the Arctic Sea, which was still frozen, and arrived in Leningrad during its white nights.

The cargo was hastily unloaded and immediately the installation of the milling machines was begun.

The members of the project from the Soviet side were the factory boss, Yuri Yakovlevich Firusukov, who was the main person in charge; Chief Engineer Gusef; the main software technician Suichov; an engineer named Robokov, an engineer named Shaydrov, and electrical engineer named Anashkin, and an excellent engineer only known as Yura. [names transliterated] Several factory workers also participated.

Gusef told me, "We can increase the number of men as required. If you let us know in advance, we are willing to supply anything, including tools, metal implements, and gauges."

Just as Gusef promised us, over 50 men, a large portion of whom were procured from places unknown, handled the installation of the heavy equipment.

As far as the procedures for construction were concerned, we first opened the crates while building a solid foundation at the same time.

The work of excavating a pit, laying down packed cobblestones, and pouring concrete was work to be done by the Soviet side according to the contract in accordance with the foundation design specified by Toshiba Machine. This belonged to a construction area in which the seller did not participate, and unless this [foundation] were firm, installation precision would be impossible. It was necessary to supervise constantly to ensure that a firm

foundation would be completed. Digging a hole 10 meters deep at a marsh land site where water would be hit was considered to be a hopeless effort in terms of foundation construction.

The difficult construction, which might have ended at any time, moved forward slowly nevertheless with employees working day and night so that in a week's time, the foundation stone managed to be packed solid.

The crate opening work was equal to this in difficulty. If the opening of the boxes itself was entrusted to robust Russian workers, they could have simply smashed the boxes open, but the problem was that they had to be careful not to damage the contents and not to lose a small item even now and then. So the crates were stored carefully. Robokov was asked to be in attendance and kept steady watch so that not even one item would disappear. However, even though he checked, an item disappeared, and even though it was not an expensive item, time and effort were required to reorder it from Japan.

In any case, the item was lost.

I do not want to slander them for slander's sake, but, in truth, the Russians, no matter how intellectually superior they are individually, have a weakness when it comes to controlling their desires. It is close to the truth that they can be considered nothing other than bad customers. This is unrelated to their education and status.

The Soviet Union is the number one country in the world in terms of theft, infidelity, and divorce, and I think this is because the Russians cannot suppress the source of their human desires. It would appear that a certain major portion of basic human emotion is missing in them. The character of the Russians is not inferior. Rather it relies on a difference of subtle nuance in the individuality of the people. This appears to arise in the differences in the roots of the various nationalities. For example, while they are a people who excel musically, they are also a people who do not extend themselves physically to other peoples in any way.

A while ago I spent several days with an engineer from a manufacturer located in Kansai who had delivered a space chamber to be used for astronaut training to a research institute in Moscow and who was conducting its operational tests after installation. The entrance to the area where the chamber was installed was watched closely. There was a door which opened and closed by a magnetic card, which was unusual for the Soviet Union at that time, and a room where an identification card was required for entering and exiting. In spite of this double security, small items, tools, pencils, and electric items left within the chamber were frequently stolen. It left us stunned.

The commitment of this sort of petty theft by people contributing to the training of the astronauts, which was unthinkable in Japan in general, existed in the Soviet Union, which does not have enough consumer goods.

This does not seem to be a problem of good or bad, but something stemming from the character of the people.

The workers opening these crates were supervised more closely. Someone was always in attendance watching, and the work proceeded by the man-to-man method. Consequently, the opening of the crates took three weeks to complete from start to finish. During this period, the basic foundation was completed with difficulty, and the preparations for installing the machinery were finished.

'Human Copy Machine'

Around this time Olstad, a numerical controls [NC] expert, and Helan, a computer software programmer, both from Konigsberg Ltd., arrived in Leningrad. They joined our Japanese group, and the work began.

Three of the four 9-axis control milling machines ordered were unloaded at the Black Sea port of Il'ichevsk and arrived in Leningrad by rail. Two of these were to be installed at the main plant of the Baltic Shipyard. The fourth, which arrived directly at Leningrad, and the other to come via Il'ichevsk were transported to the propeller factory and installed in accordance with the Tokyo Machine installation instructions. In the contract, there is a clause that reads, "The personnel of the buyer are to be trained and advised about installation, adjustment, and operational testing, until normal operations begin of the machines delivered at the buyer's factory in the Soviet Union." Until the four machines were running normally, the Soviet Union withheld payment of 10 percent of the contracted amount as a guarantee.

Therefore, the four machines were completely installed and tested operationally, and required proof that they were of the quality specified in the contract. Unless there was a protocol which contained the results of the operational testing, which were exchanged between the seller and the buyer at this time, the 10 percent guarantee would not be handed over. However, the Soviet side insisted that only Soviet personnel could install and test operationally the two machines at the main plant.

The machines were large and extraordinarily heavy, and unless the assembling were done skillfully and carefully, the required micron order precision would not be obtained. Engineers using the diagrams and instructions for the first time, no matter how excellent they were, would not be able to install the machines on their own and achieve the guaranteed precision. We stressed this fact and requested the participation of Toshiba Machine but were promptly turned down.

While no conclusion had been reached on how to resolve this problem, installation of the first machine began anyhow. When construction was in full force, an unusual phenomenon appeared.

The Soviet workers already looked weary from the beginning of work in the morning. Their work was sluggish and their hollowed out eyes shone on their oily faces. Their degree of exhaustion intensified daily. It truly befuddled us at first how powerful Russians, whose work was to lift blocks of steel, could weary without difficulty.

The Soviet Union always scatters the deployment of important military equipment among several sites to avoid the total destruction that would be caused by pinpoint bombing. The place where these two machines were being built was near the ship slips and docks, areas where foreigners were not allowed. Toshiba Machine engineers were not permitted to enter there. In short, the Russians sent the Japanese home early, copied completely what the Japanese had done during the day, and repeated the same procedures through the night, thereby completing the installation.

The Russians observed intently what the Toshiba Machine engineers did during the day, crammed the work process into their brains, and faithfully reproduced the order of assembly. The installation was completed by photographically recalling even such things as how bolts were fastened to achieve a complete copy similar to a video replay of the original.

However, just starting up a motor through assembly and electricity is no way to give life to a machine and draw out its useful functions. Rather, the necessary data must be provided to the memory of an NC device equivalent to a human brain. This is akin to inputting a dictionary function into a word processor and is called the "writing of a ROM [read only memory]." This work is absolutely impossible to copy by sight, and cannot be achieved without the accumulation and experience of technology. Consequently, the assistance provided by Olstad from Konigsberg was indispensable. The need emerged to have Olstad enter the secret [Soviet work] area. What were the Soviets to do? Olstad, who was in his late 30's and had spent half his life as an earnest engineer in the rustic Norwegian town of Konigsberg, had remained single because he had been betrayed by women many times and had sworn never to get married. When we chatted during work breaks, he told us that he disliked women. In a sermon to his fellow male workers on women (in particular, Russian women), he was not afraid to declare his distrust of women. Yet, Olstad had not been in Leningrad two months when he married a Soviet woman. We wanted to simply celebrate this as a wedding bonding Olstad with a Soviet woman in a love relationship which they came to of their own free will. However, we speculated that there was, at the bottom of this, the influence of "Soviet free will."

Using the NC devices and computers without seeking the aid of Konigsberg was difficult. In particular, repairs to be made in the future would absolutely require Konigsberg assistance.

Weddings between foreigners and Soviet citizens are not permitted readily. Permission requires complex procedures, and even if things go smoothly this ordinarily takes half a year. Olstad's being able to marry in a mere

two months was truly an exception within an exception and had to require the special influence of the Soviet authorities from the Baltic Shipyard. It could only be expected that the woman who married Olstad, not to mention Olstad himself. would feel a lifelong obligation because of this. Naturally, Olstad personally felt a special kinship with the plant and would be in a cooperative state of mind.

The Lure of Marriage

Fuirusukov, Gusef, and Suichov attended the wedding ceremony from the plant, but nobody was invited from Toshiba Machine, whose workers had been close [to Olstad] and which was the purchaser of the NC equipment. On the contrary, the Toshiba Machine workers were informed unexpectedly of the wedding the day following the ceremony.

Of course, Olstad was able to write the ROM for the two milling machines in the prohibited area.

Another Norwegian there was a Mr Helan, a computer engineer about 50 years old. At the same time, he was also a lecturer who had received a lectureship in electronic engineering at a local university. He was a bit too old as a computer programmer, and his mind proved to be very weak. He spent his time searching for young women and went about running in and out of hotel bars and restaurants from the first day he arrived in Leningrad. In the end, he was injured from a "hard blow."

He had already been in the Soviet Union for about 2 weeks when the installation of the programming center ended smoothly and the final thorough adjustments began. One morning, blinking his red eyes from lack of sleep, he asked me the following question with an extremely intent expression, "Mr Kumagai, is there a good medicine in Russia to kill small bugs which stick to humans? If there is, would you let me know how I can get hold of it?"

"Are the bugs ticks?"

"I do not know what to call them in English."

"Where are they on you? Let me take a peek." Suddenly I was struck by the look of embarrassment on Helan's face. I realized that skirt-chasing foreigners frequently have illicit sex and that something akin to a slight traffic accident often occurs.

I then said, "Mr Helan, I suppose these are bugs clinging to your most private male parts. Well, the word in Russian is mandavoshka. In the past, the medicine for mandavoshka was sold at drug stores. However, drugs containing mercury are prohibited from being manufactured now, and this drug is not sold anymore. You will probably have to ask someone at the plant."

His face became full of joy, pitiful wretch that he was, and, saying over and over again that he could always count on me, he left the waiting room to do battle with the computer on the fifth floor.

Because he asked Yura, one of the Soviet engineers, and received a soft homemade medicine, Helan completely opened up to him and became close to him, sharing small secrets with him.

The Soviet Union still has crab lice.

Crab lice, which have not been seen in Japan for a long time, are rampant in Moscow and Leningrad since the Soviet military invasion of Afghanistan, and they are thriving in the bodies of young female prostitutes.

Recently, herpes, gonorrhea, and mandavoshka are inhabiting Russia. And now the rumor that 15 men and women have entered Soviet hospitals with AIDS is spreading among the young women and causing a panic.

Just as the Soviet people say, Russia has everything.

In the section of the propeller plant affected by the installation of foreign imported goods, ship propellers of all shapes and sizes are produced by a three-shift, 24-hour a day operation. This plant is a vertically integrated plant producing propellers from casting to finishing. More than 10 milling machines, both foreign and Soviet, are fully operational day and night. More than 20 medium size, 50-meter diameter propellers are produced per month. Annually, over 250 propellers are produced. This approaches a production volume meeting the demand of all Soviet vessels.

The surface of the propeller has a great impact on the propulsion of the ship. The speed of the ship is largely governed by the milling precision of the propeller surface. A ship's propeller is eroded electrically by the static electricity produced within the vessel during the voyage, and surface resistance increases. This incurs a marked decline in the speed of the ship naturally, and the propeller needs to be exchanged frequently to prevent this. In other words, propellers are expendable, and a space must always be produced so that it can be exchanged with the original. Leningrad is the geographic center of the four Soviet fleets and is the most appropriate place for a plant with this objective. All the propellers manufactured here, including the spares, are shipped to Soviet naval bases by sea or rail.

Japanese, Norwegian, and French capital equipment have been introduced into this small section not even 20 tsubo square to operate day and night to achieve this objective.

A multi-axis propeller milling machine which a French company delivered in the latter half of the 1970's (I cannot prove whether this was done in violation of COCOM) is fully operational, although I could not see it in operation since the turntable was under a canvas shelter.

This is quite large by Soviet standards, and three firms from three Free World countries (Japan, France, and Norway) each have delivered equipment to this plant in contravention of COCOM controls. Based on this inference, I wonder how much capital equipment has really secretly been brought to the main factory of the Baltic Shipyard and into the thousands and tens of thousands of plants across the Soviet Union by Free World firms in violation of COCOM controls?

If this small essay has any value as a document, I hope it will be to vindicate the honor of the Toshiba Machine and Norwegian technicians who struggled together at the installation site.

If the Soviet Union asked companies, who would decline at an instant to sell it a nuclear missile, for a machine to manufacture small precision fasteners (necessary in assembling nuclear warheads), one hundred firms out of one hundred firms from capitalist countries would agree to do so, even if they were full of suspicions about the end use of the fasteners. In the current climate in Japan, the leading economic power and a place where making money has become a religion, corporate behavior does not deviate from this pattern. That would especially appear to be confirmed in its trade with the Soviet Union.

If the company told its technicians on site to proceed in spite of the knowledge that a "fastener manufacturing machine" ran counter to COCOM controls, the technicians would do their best and devote all their efforts to completing the best product. That is similar to the thinking of the British officers and men, who although prisoners of war, proceeded to accept the command of the Japanese military, fully display their abilities for that military, and build the bridge on the River Kwai.

The technicians from Toshiba Machine and Konigsberg never thought, while at work at the site, that the milling machines would be used for anything other than to manufacture screws for tankers and freighters. However, even if the knowledge had reached here that these might be used for warships, they actually could not have instantly abandoned their place of work and committed sabotage. They, therefore, could do no more than their personal best as employees.

Uses of the Propeller Milling Machines

The United States has made the severe criticism that the main reason Toshiba Machine exported the 9-axis milling machines to the Soviet Union was to improve the silence of Soviet nuclear submarines.

The question is did the 9-axis milling machines actually contribute to the improved silence of the submarines, or, what other new methods did the Soviet Union develop? I am entirely a layman in military affairs and shipbuilding, but as an individual who has seen a Soviet propeller milling plant, and as an individual who had a premonition about the present situation

and intentionally did his best to photographically remember the work area in the Soviet propeller factory, I would like to take up this problem on my own.

In order to see the causal relationship between Toshiba Machine's propeller milling machines and the remarkably improved silence of Soviet submarines, we will compare the time when the milling machines were loaded for shipment and the time they were fully operational with the time Soviet submarines with improved silence were launched and the time these submarines were commissioned.

The shipping dates of the milling machines (four 9-axis machines and four 5-axis machines for a total of eight machines) were:

9-axis machine 1 - December, 1982
9-axis machine 2 - February, 1983
9-axis machine 3 - May, 1983
9-axis machine 4 - June, 1983
5-axis machines 1 and 2 - April, 1984
5-axis machines 3 and 4 - May, 1984

Moreover, a total of 12 improved cutter heads and applied software for each of the 9-axis milling machines were exported (three per machine) in June, 1984. The entire shipment arrived at the Baltic Shipyard by way of Il'ichevsk in July.

These eight milling machines began operations after test operations on the following dates:

Two 9-axis milling machines - December, 1983

The two 9-axis milling machines installed by the Soviets alone could not have been before this time.

Two 5-axis milling machines - December, 1984

The two 5-axis milling machines installed by the Soviets alone could not have been before this time.

To sum up the above, 9-axis milling machines began to be used in earnest by the Soviet Union itself in early 1984, and there were absolutely none before that time. Moreover, as stated subsequently, prior to December, 1984 when improved cutter heads and their software were attached to these machines and the machines were readjusted and performed more assuredly, the Soviet Union used these machines for a time without adequate performance. There were many places where the cuts were not good and the propellers could not be used. If we look at this set of facts. we can declare that it was absolutely impossible for high precision propellers to be completed by the Soviets themselves before January, 1985 from the 9-axis propeller milling

machines delivered by Toshiba Machine. Moreover, it was also impossible to similarly manufacture a propeller by means of the 5-axis milling machines prior to this time. This is because the 5-axis milling machines were tested in operation at the end of 1984 and then handed over as finished products. The argument is absurd that Toshiba Machine milling machines were used before 1985 to produce high performance propellers used in nuclear submarines. I can without any doubt declare this to be impossible.

Let us next examine the data published in the United States on Soviet submarines which states that their silence has improved markedly.

The U.S. data is from "Guide to the Soviet Navy" and "Navy Times."

The Soviet nuclear submarines whose silence has improved are:

1. Sierra-class, 7,550-ton, 110-meter long, Gorky Shipyard built first confirmed in 1983, first commissioned in 1984.

2. Akula-class, 8,300-ton, 107-meter long, Komosomal'sk Shipyard built, first confirmed in 1984, first commissioned in 1985.

3. Mike-class, 9,700-ton, 122-meter long, Severodobinsk Shipyard built, first confirmed in 1983, first commissioned in 1984.

4. Victor-3 class, 6,300-ton, 106-meter long, Admiralty Shipyard and Komosomol'sk Shipyard built, 20 commissioned from 1978 to 1985.

It is impossible that a Toshiba Machine milling machine could have manufactured the screws of the Sierra-class and Mike-class submarines, which were commissioned in 1984. Although it is also impossible for the screws of the latest of the Victor-3-class submarines and the Akula-class submarines to have been produced by these machines, they were launched in 1984, and the screws were installed after the launching ceremony. Nevertheless, having the submarine dock again after the launching just to append the screw is unnatural and logically absurd. Moreover, the Akula-class was launched at Komosomol'sk Shipyard in the Far East several thousand kilometers from Leningrad where Toshiba Machine's milling machines were installed. Looking at these facts, I cannot consider Toshiba Machine's propeller milling machines to be the direct cause of the improved silence of the latest Soviet submarines. This is the first point of issue.

The second question is if Toshiba Machine's milling machines contributed to the improved silence of the Akula-class and Sierra-class submarines, why were only the most recent submarines equipped with the propellers manufactured by this machine? Why for just these four types of submarines did the noise become less? With regard to the production capacity of Toshiba Machine's 9-axis milling machines, about 400 hours are required to produce a propeller 11 meters in diameter and with 11 blades. At the Baltic Shipyard, which

operates around the clock, the time required for one milling machine to finish one screw, with preparation time added in, would be 20 days at best. If the four 9-axis machines were fully operational, the plant would be able to produce four screws a month at the very best. Four screws multiplied by 12 months works out to 48 propellers a year. From the end of 1984 when the installation of the machines was completed, the machines began production operations, and over two years have passed since then. If the screws manufactured by Toshiba Machine's milling machines were the primary reason behind the improved silence of the submarines, then, theoretically, today, when over two and a half years have passed since operations began, there would likely be 96 of these new screws for Soviet submarines, given that 48 multiplied by two years is 96. Virtually half of the Soviet Union's submarine fleet must have improved silence. However, according to the U.S. data, the submarines with improved silence are only over 10 submarines of the Sierra, Akula, Mike, and Victor classes. Ship propellers are expendables and simple to exchange. If that is the case, why weren't other submarines provided propellers with improved silence and their noise reduced? This is the second point at issue.

The third question is the technological limits of milling machines. Toshiba Machine's propeller milling machines are devices that faithfully process equipment in accordance with data by a computer processing a designer's ideas and putting the data obtained into an NC device. The machine does not have the ability to logically create a propeller on its own. As for the point that these machines are considered to be skilled workers that finish the product in accordance with directions, they can do no more than excellent work. They do not have the ability to cut according to their own ideas or their own discretion. They can do nothing more than produce a fine piece of work in a short time, which is better than mediocre workers. Poor workers require three men to complete the work of one. Of course, the work is finished in several stages.

Were improved silence possible by these machines, we could expect that the older machines also could produce silent propellers if the milling was diligent over a period of time. However, the Soviet Union has genuinely built, suddenly from a certain point in time, submarines making little noise. I can only imagine that this drastic improvement in silence can be from a cause other than the screw.

If Toshiba Machine's milling machines are to be considered a threat in terms of the strategy against Soviet submarines, the threat lies in the remarkable reduction of the time required to manufacture a propeller. If the eight 5-axis and 9-axis milling machines are fully operational, then virtually all Soviet surface vessel and submarine propellers could be converted to new propellers one or two years into the future. Equipping the ships with propellers that are more finished is an advantage of the Soviet fleet in terms of fuel costs, speed, and muffled noise. This would not be easy for the Free World camp. In the case of submarines, frequently changing the

propeller would bring about a shorter period for the soundprint before it changed and would make the submarines even more difficult to detect. Moreover, the Japanese media have no interest in the fact that these propellers could also be supplied to the nuclear-powered aircraft carriers being built.
I thought of this at the time, as I will describe later, from two standpoints: 1) the orders that had been placed for other machines, and 2) the fact that the screws that a 9-axis milling machine can process are extremely large. We must make this point sincerely to better counter that alarms that U.S. authorities are sounding.

Severely censuring Toshiba Machine as a practitioner of illegal exports endangering the safety of the West is not unreasonable. However, who could we name as the evil ringleader? Would it be best to meticulously tame the firm and associated businesses that were involved in these activities and to neglect the ringleader who conspired to cheat by both appeasement and intimidation? After we clearly ascertain whom the culprit is and whom his followers are, will we still criticize Toshiba Machine? Is it all right to allow the Soviet Union, which plays upon the weaknesses of the corporations of capitalist countries by using the "threads of a spider" such as secret spying and illegal activities to steal high techmology, have the last laugh?

To be sure, we are guilty. That is beyond dispute. However, isn't it the Soviet Union which ridicules the present situation more than anyone?

Mysterious New Allusions

When we reached the stage of completing the operational testing and handing over the machines without incident and began the draft of a protocol to document this, we received a special request from Plant Manager Firusukov to meet the plant manager of the entire Baltic Shipyard. We were extremely interested in meeting face to face the person in charge of 5,000 employees and the building of ships supporting a wing of the Soviet military, and we assented in response to Firusukov's enticement that "there would also be important business talks."

Firusukov introduced us, hurriedly made an opening statement, and we began to exchange toasts of vodka.

The next day when we had lunch with Baltic Shipyard Plant Manager Shierushinev, Firusukov supplied us with a tantalizing allusion by saying that this came about because of permission from higher authorities.

There is a substitute "machine that processes spiral poles 20 meters in diameter and is a kind of fastener that deepens the grooves of a drill." The depth of a groove, or to put it another way, the height of a mountain of fasteners is 70 centimeters, and this machine, known in Russian as "wadamyet" can cut this continuously. By rapidly rotating these incredibly large fasteners, water can be hurriedly pushed aside and propulsion is obtained as a reaction.

This is a kind of screw that can be viewed as an "expectoration machine." The technological aspects and dynamic logic of propulsion are things that, I am sorry to say, a layman cannot understand at all, but I quickly asked Wako Koeki to investigate this. The data needed to select an appropriate machine, such as objective and uses, could not be obtained, but they did say, "We suspect that the materials would be identical with those of a ship propeller, and if you could give us an estimate of the cost of a machining center [and these materials] to process these automatically, we feel these could be processed in line with our objectives. Please hurry."

This matter was transferred to the Moscow branch office of Wako Koeki and negotiations began formally with the Soviet front company, the Technology Machine Import Public Corporation.

When I heard this, I thought that this almost certainly came from the Soviets having researched and developed some kind of propulsion device, and, consequently, wanting to introduce a more superior Japanese-made machine to produce a finished product in a shortened time like the propeller milling machine. However, I did not know the truth or falseness behind my assumption. They offered a contract after little negotiation if Japan would build a machining center that could handle this sort of complex machine process. They also offered us an ATS (automatic drill setter) worth about one million dollars.

They said, "We would like to use it experimentally and if the results are good, we will sign additional contracts." However, because the Toshiba Machine case had come to light, procedures were taken to cancel the contract immediately.

These were business talks that began through the permission of the plant manager of the Baltic Shipyard, and there were talks involving ties with ships, their propulsion technology, and, this is entirely my own idea, the rapid turnaround of the ship. When I read of the idea of a silent submarine in Tom Clancy's "The Hunt for Red October," I immediately thought of these talks. In layman's terms, if a submarine can expectorate water like a squid and move forward, it will not make a sound. My guess, of course, is that the Soviet Union is thinking of that sort of submarine, but I cannot shed more light on this.

A centrifuge was the topic of business talks beginning at the same time as these [talks].

This large centrifuge would test the aptitudes of the jet pilots of the aircraft carried on board the first genuine C/TOL aircraft carrier (horizontal landing aircraft carrier) to be possessed by the Soviet Navy and would be used in early training. The aircraft carrier itself was built at the Nikolaev Shipyard on the Black Sea coast. The Soviets required that the centrifuge have the strength and ability to endure an acceleration of 9G. The deck landing on an aircraft carrier has an impact that can best be called

"a controlled crash," and a large-scale centrifuge is needed to simulate this impact. There is a device that connects this to a computer and observes and records the medical and physiological changes of the persons undergoing the testing. Micron Corporation and Techno International Corporation are in charge of the computer. The estimated cost of the entire package was about ten billion yen, but when the Toshiba Machine illegal export incident was discovered, this was cancelled [on the pretext of] accommodating the Soviet budget. The front company for this was the Technology Machine Public Import Corporation.

Swedish-manufactured Crane

If you read what follows as a product of my imagination or a sort of SF [science fiction], that will be fine. However, it is based on published facts, data, and my own experiences. There is a nuclear aircraft carrier named the "Kremlin," for the seat of all power in the Union of Soviet Socialist Republics. The existence of this aircraft carrier is clear from the satellite pictures taken on its being built at the Nikolaev Naval Yard on the Black Sea coast of the Soviet Union. These pictures were published in the August, 1984 edition of the British military journal, JANE'S DEFENSE WEEKLY.

According to data analysis from the KH11, the U.S. digital transmission photographic spy satellite, the length of the "Kremlin" is about 300 meters, the displacement is 75,000 tons, the output is above 240,000 horsepower, and the top speed is estimated to be about 33 knots. It is an enormous aircraft carrier, larger than the United States Navy's Midway and rivaling the Enterprise. The original name of the ship was the Sovietki Soyuz, but this was changed in 1985 to the Kremlin, and was changed again in 1987 to the Leonid Brezhnev.

The aircraft carrier that has begun to be known as the Leonid Brezhnev, was launched in December, 1985, will begin sea trials in 1988, and is expected to be operationally deployed in the 1990's to the North Sea Fleet, with Murmansk as its home port. At the shipbuilding slip of the Nikolayev Shipyard, the construction of a second carrier has already begun, and if this is completed, it will be deployed to the Pacific Fleet at Vladivostok. A third and fourth carrier, for a total of four in all, are scheduled to be built.

The Black Sea coastal port of Nikolayev was selected for the construction of these ships because it is a warm region where work can be carried on during the winter. A gantry crane, without which the construction of huge aircraft carriers cannot occur, was quickly imported from Sweden as a result. A door-shaped crane bestrides the slip, 60 meters tall and with the ability to hoist 1,000 tons. The Soviet Union manufactures cranes with the ability to hoist 1,000 tons, but they are crude when it comes to the subtle adjustments of raising and lowering objects and are inappropriate for the construction of an aircraft carrier requiring high precision. The Swedish-manufactured crane, which guarantees hoisting precision to within several millimeters was

purchased through the Technology Machine Import Public Corporation. Existing shipbuilding slips could not be used for the Brezhnev because of its enormous size. Two slips are being used with the construction divided in two. The two halves are being built parallel to one another with the first half being built on a slip to the right of a Kiev-class ship, and the latter half on a slip prepared next to that one. This is the first large aircraft carrier construction project in Soviet history, and the work is progressing slower than expected. When an unforeseen event occurs, in particular when the lack of capital equipment and materials is the cause, the Technology Machine Import Public Corporation purchases these items from a foreign firm. The foreign currency budget for the completion of the construction of this ship is unlimited, and the budget of this public corporation is accounted for specially by approval of the Politburo. That is nothing. The West appears to be building this Soviet nuclear-powered aircraft carrier. A mass production manufacturing capability is needed to build the screws for aircraft carriers and surface vessels. In fact, the Soviet Navy is right in the middle of a large expansion. One can easily imagine "9-axis" milling machines being active. The deck landing training of the crews of the carrier airplanes began around the time the Leonid Brezhnev was launched. Virtually none of the pilots of the Soviet Union have any experience landing airplanes on an aircraft carrier in the middle of the ocean. Consequently, along with the construction of the Brezhnev, runways similar to that on the flight deck of the Brezhnev have been designed, and deck landing training has secretly begun at the Saki Naval Air Base on the Black Sea coast and at Ramenskoye Air Base in the Moscow suburbs.

How the impact of a deck landing is to be endured is a major problem. In addition to observing the physiology of the new pilots and testing their aptitudes, the procurement of a test device to develop resistance to the impact was an important task. The device itself is not a strategic item that runs counter to COCOM controls. It is nothing more than a large and powerful centrifuge. A strong arm with a pivot in the center will be installed to fix tight a cabin to accommodate those undergoing the tests at both ends of the arm. This will be rotated at super-high speed. A simulation will be carried out by sudden starts and stops, creating the conditions similar to a deck landing. In addition, the centrifuge will be connected to a medical measurement device to observe the physiology of the person undergoing the tests within the cabin, and the centrifuge will also be connected to a computer to observe and record the bodily physiological changes within the crewmen to the acceleration and the impact. The control of the centrifuge will be carried out by the computer. The cabin, which is outfitted with an airplane seat to endure an 8G impact and test pilot equipment for a warplane, is heavy, weighing over one ton and needs an extremely powerful motor to suddenly rotate this and suddenly stop this at an acceleration of 8G. The machines, tools, and devices have been procured from various countries in the world and are being installed at the air base. As a result, the training of the flight crews of the aircraft carrier Brezhnev has begun on a 24-hour system. The nuclear-powered aircraft carrier will probably be deployed to the Pacific Fleet at the Far East port of Vladivostok. That is not so far off into the future.

Along with the manufacturing and loading of the 9-axis milling machines, talks were begun on the purchase of 5-axis milling machines. This time the front company for the Soviet side was not the Technology Machine Import Public Corporation, but the Industrial Machine Import Public Corporation. The reasons for the change of front companies was because Trotsky, who had been in charge of the 9-axis talks for the Soviet side, had been promoted and appointed vice president of the Industrial Machine Import Public Corporation, and he transferred Toshiba Machine matters to his own public corporation. During these 9-axis talks, Trotsky decided to undertake, as vice president, the roles undertaken previously by Vice Presidents Oshipofu and Araberudov. Yuri Elise'ev of the Industrial Machine Public Corporation was assigned [by Trotsky] to be in charge. A contract was signed on 1 April, 1983 through a process identical with the 9-axis process. The installation and handing over of these 5-axis milling machines was in December 1984.

Traces of the New Talks

The "expectoration machine," or in other words, the machining center used for spiral processing of fasteners was handled by Oshipov, a vice president of the Technology Machine Import Public Corporation, and Marutoinushkin, who was formerly employed in the Soviet trade delegation in Japan. The point of signing the contract has been reached, but the contract was cancelled when the Toshiba Machine COCOM violation was discovered.

The Technology Machine Import Public Corporation was also the front company for the large centrifuge negotiations, which continued on a technological level, but these talks also stopped when the Toshiba Machine incident was unearthed, with the Soviet budget as the pretext. This case was handled by Division Chief Bulgakov and Ifimov, who was formerly with the Soviet trade delegation in Japan.

Both cancelled projects, the machining center and the centrifuge, were unrelated to the Toshiba Machine case. However, it was suspected that the purpose of each was closely connected with the strengthening of the Soviet Navy. The Soviet Union can be expected, by some means or other, to send out feelers again to obtain these machines, attempts which were aborted this time.

My experience at the Baltic Shipyard in Leningrad was essentially entirely different with trade with the Soviet Union up to this time. COCOM violations had begun to consist of a small corner of daily operations of this trade. How the average businessman should best handle this is a serious problem that is anybody's guess. My understanding at the time was that I and Japan were lending a great deal of energy to produce a large navy. Faced with this situation, I could have made the following choices: 1) say that I had no experience with illegal exports of propeller milling machines at

the Baltic Shipyard and continue exports to the Soviet Union as they had been; 2) recommend to the company that they cease the illegal exports; 3) resign and take up work entirely unrelated to the Soviet Union; 4) report the illegal exports to the supervisory authorities; and 5) report to the organization that supervises the outflow of strategic materials to the Soviet Union.

For awhile, I kept my mouth shut and thought about taking up work that had no connection with trade, such as being a patrolman, but the nightmare of Leningrad and the intrigue of the Soviet Union did not leave my brain. As if haunted by wild and crazy illusions, my thoughts centered on the Baltic Shipyard and my fears revived. Exhausted from thinking, I wrote a letter to the chairman of COCOM. A half a year had passed since I resigned.

I do not really know whether what I did was good or bad. I do not really know whether it was truly a plus or minus for Japan. I do not really know what sort of impact it will have on the Free World camp. However, I am certain that this will act as a minus for the Soviet Union. The "special channel" that the Soviet Union had built diligently with Japan will probably be ruined. At the very least, some of the channel will be destroyed. As certain as I can be, some day, by someone, and somehow the "underwater pipe" connecting the Soviet Union and Japan will again continue to illegally send information and materials forever.

In December 1985, I translated my letter to COCOM into English, and mailed it from a post office close to my home, while outside the New Year's Eve uproar had begun in the streets.

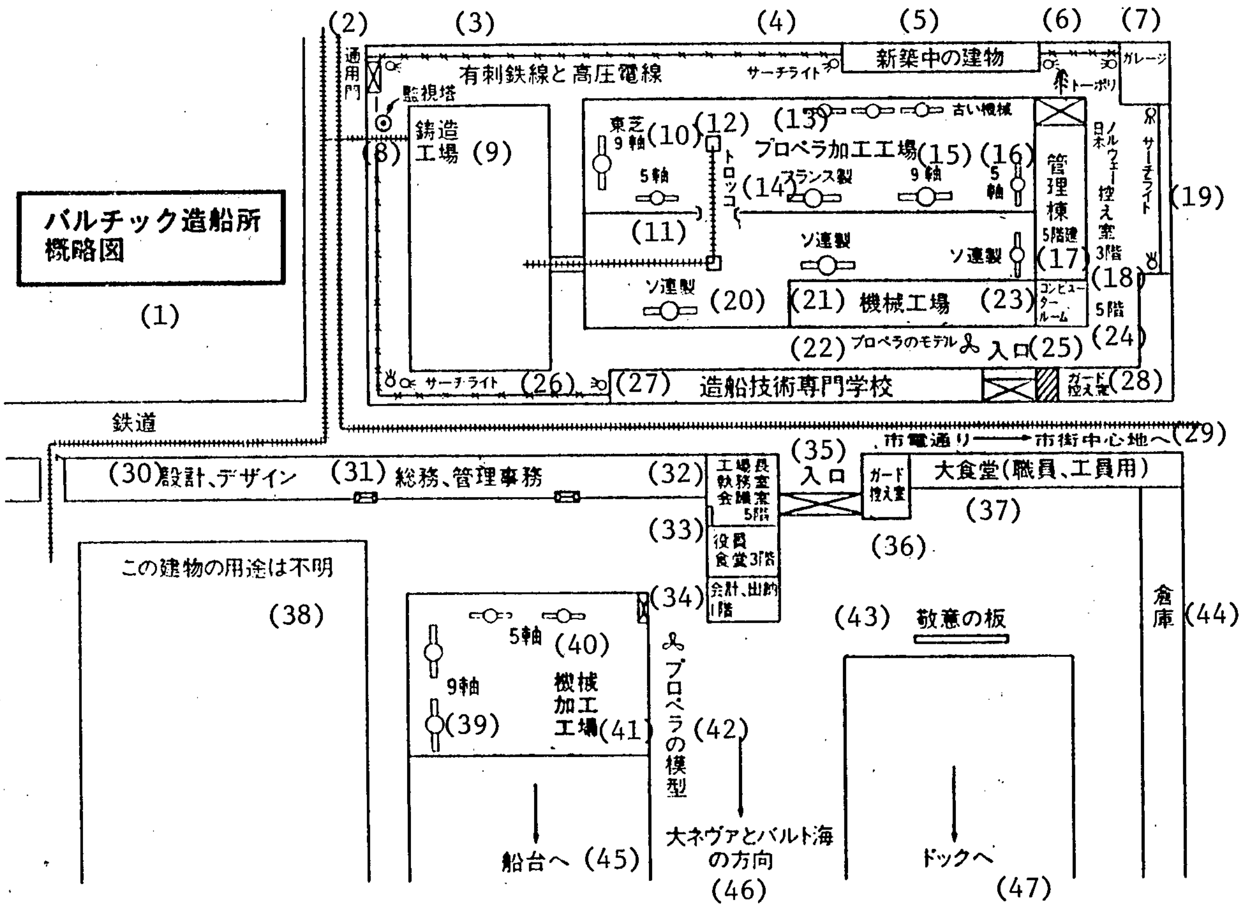


Figure 1. Outline of the Baltic Shipyard

Key:

1. Outline of the Baltic Shipyard
2. Side gate
3. Barbed wire and high voltage line
4. Spotlight
5. New building (in process)
6. Tow/Pull Machine
7. Garage
8. Guard tower
9. Manufacturing factory
10. Toshiba 9-axis

[Key continued on following page]

11. 5-axis
12. Truck
13. Propeller milling machine
14. French-manufactured
15. 9-axis
16. 5-axis
17. 5th floor management office
18. 3d floor Japan and Norway waiting room
19. Spotlight
20. Soviet-manufactured machines
21. Machine plant
22. Propeller model
23. Computer room
24. 5th floor
25. Entrance
26. Spotlight
27. Shipbuilding technology specialty school
28. Guard room
29. Tramway-towards city center
30. Drafting, design
31. General affairs and management office
32. 5th floor factory head's office and conference room
33. 3d floor executive dining hall
34. 1st floor accounting and expenses office
35. Entrance
36. Guard room
37. Big dining room (used by white-collar employees and factory workers)
38. Use of this building is unknown
39. 9-axis
40. 5-axis
41. Machine milling plant
42. Propeller model
43. Placard of honor
44. Warehouse
45. To the shipyard slip
46. Direction to the Greater Neva and Baltic Sea
47. To Dogu

12259/8309
CSO: 8129/4550

STATUS OF MAGNETICALLY LEVITATED VEHICLE (MAGLEV) DEVELOPMENT

Tokyo JIDOSHA GIJUTSU in Japanese Feb 87 pp 166-170

[Text] 1. Introduction

A maglev is a generic term for a vehicle operated using a linear motor. The word "maglev" refers to a magnetically floating vehicle currently being developed by Japan Railroad (JR), and which is called a "linear motor car." The magnetically floating vehicle is called maglev (magnetically levitated vehicle) in English.

There are several maglevs in existence in addition to the one being developed by JR. They include the Birmingham Airport shuttle in England (between the airport terminal and England's National Railroad Station, distance: 600 m, began operation May 1984, operating speed: 50 km/h, no charge), HSST by Japan Airlines, and Trans-Rapid in West Germany. These maglevs have been constructed using the absorption method which employs a normal conducting magnet. The one being developed by JR, however, employs the induction repulsion method which uses a superconducting magnet.

Since liquid helium is indispensable for superconducting magnets, current thought is that its development is questionable. Critics say that its development is a very item-consuming process due to the excessive difficulty. However, the development of this maglev originates from the idea that it is necessary to get a ground transport system for the next generation having the maximum speed of approximately 500 km/h. In order to realize this speed, a superconducting system is necessary because this system enables the joining of a sufficient floating height (about 100 mm) with an absolute noncontact situation between a vehicle and a guideway.

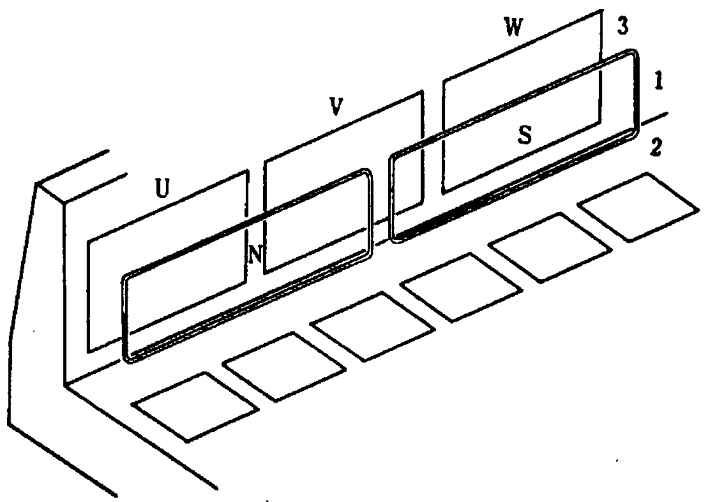
JR started its development of the superconducting system in 1970. At that time, there was essentially no accumulation of technology either for superconducting magnets or the induction repulsion method for application to vehicles. Accordingly, starting from theoretical analysis, basic experiments, low-speed running tests at JR's technical laboratory, and the construction of the Miyazaki experimental railroad and its high-speed running tests were required. This process took a very long time. Fortunately, however, the ML 500 experimental vehicle succeeded in running at the maximum speed of 517 km/h, exceeding the objective, in December 1979. Beginning in 1980, the expected results were achieved in the running of a several-carriage MLU 001

experimental train, experimental running with passengers, and running experiments involving passing through irregular guideways. Finally, the production of a prototype vehicle, the step just prior to production of a commercial vehicle, was attained.

In this paper, the basic structure of the magnetically floating-type railroad developed by JR is briefly introduced. Then, a new cycloconverter, which began use in December 1986, is also introduced. Future plans are also discussed.

2. Basic Construction of Floating-Type Railroad

Coil arrangement (one side) which is the basis of this floating-type railroad is shown in Figure 2. A superconducting coil is placed on the vehicle so as to have an alternating magnetic arrangement toward a running direction. A ground coil for floating is a short-circuit coil. It is arranged so that it interlinks with the magnetic flux of a superconducting coil. When the superconducting coil passes over the ground coil, an induced current is generated. Due to this induced current and electromagnetic force of the superconducting coil, a vehicle is repulsed from the ground, and it floats.



No	Name of coils	Materials	Circuits	Electric current
1	Super-conducting coils	Nb-Ti alloy	Loop	Permanent electric current
2	Ground coil for floating	Aluminum for electricity	Loop	Induction electric current
3	Ground coil for propulsive guide	Aluminum for electricity	Three-phase four-wire type	Variable frequency alternating current
			Null flux loop	Induction electric current (on inclined vehicle)

Figure 2. Arrangement of Coils

With an induced current, when a vehicle does not move, there is no force to push the vehicle up from the ground. Therefore, supplemental supporting wheels are needed. However, no control is required for the floating of a vehicle.

A propulsive guide coil is an armature coil placed under the three-phase and one-layer arrangement (as described later, this name comes from the fact that the coil is also used to guide). This coil is arranged so that it is opposite an ultraconducting coil which is utilized as a magnetic pole. From both coils, an LSM (linear synchronous motor) is formed. An alternating current of variable amplitude and variable frequency, which synchronizes with the position of a vehicle, is transmitted to the propulsive guide coil from an electric power converter placed in a substation. The speed of a vehicle can be controlled by changing its amplitude. Since the ground first system (electric power is supplied from the ground side) is applied, it is not necessary to accumulate a large amount of electricity for propulsion.

Guide force is similarly generated from the principle of floating. In order to reduce the magnetic resistant force, the null-flux method has been adopted, i.e., at the ground side, the right and left propulsive guide coils, which are opposite each other, are connected to form a loop. When a vehicle is sitting on the center line of a guideway, the magnetic flux due to the right and left coils becomes zero since they cancel each other out. On the other hand, when only right or left displacement is exerted toward a vehicle, the circulating electric current is on, and restitutive force is generated.

Since propulsive guide coils are placed all along the line, it is electrically divided into sections of a certain distance. Electricity is supplied only to a section where a vehicle is running. In addition, in order to prevent fluctuations of propulsive force when a vehicle passes from one section to another section, the coils are divided into two groups, A and B. Corresponding to the movement of a vehicle, the electric power supply is successively switched by a feeder line section "break and make" switch (Figure 3). In order to detect the position of a vehicle, two methods are used jointly. One is the intersection induction line method, and the other is a method which counts electromagnetically the number of ground coils used for floating. The wireless method, used in conjunction with the application of leakage coaxial cables, has been adopted for the transmission of information between the ground and the vehicle.

3. Prototype Vehicle

(1) Composition

The production goal of the prototype vehicle (MLU 002) is not only to make a comprehensive survey of the past technological development results, but also to express clearly the image of floating-type railroad development at the final stage and to conduct final confirmation of its safety, reliability, and practical application. Since MLU 002 is scheduled for testing on the Miyazaki experimental line, it has been fitted to the structure of the guideways. As has been demonstrated with this prototype vehicle, the offering of design specifications for use in the concretization of model line planning, which has been attempted gradually, is now considered to be possible.

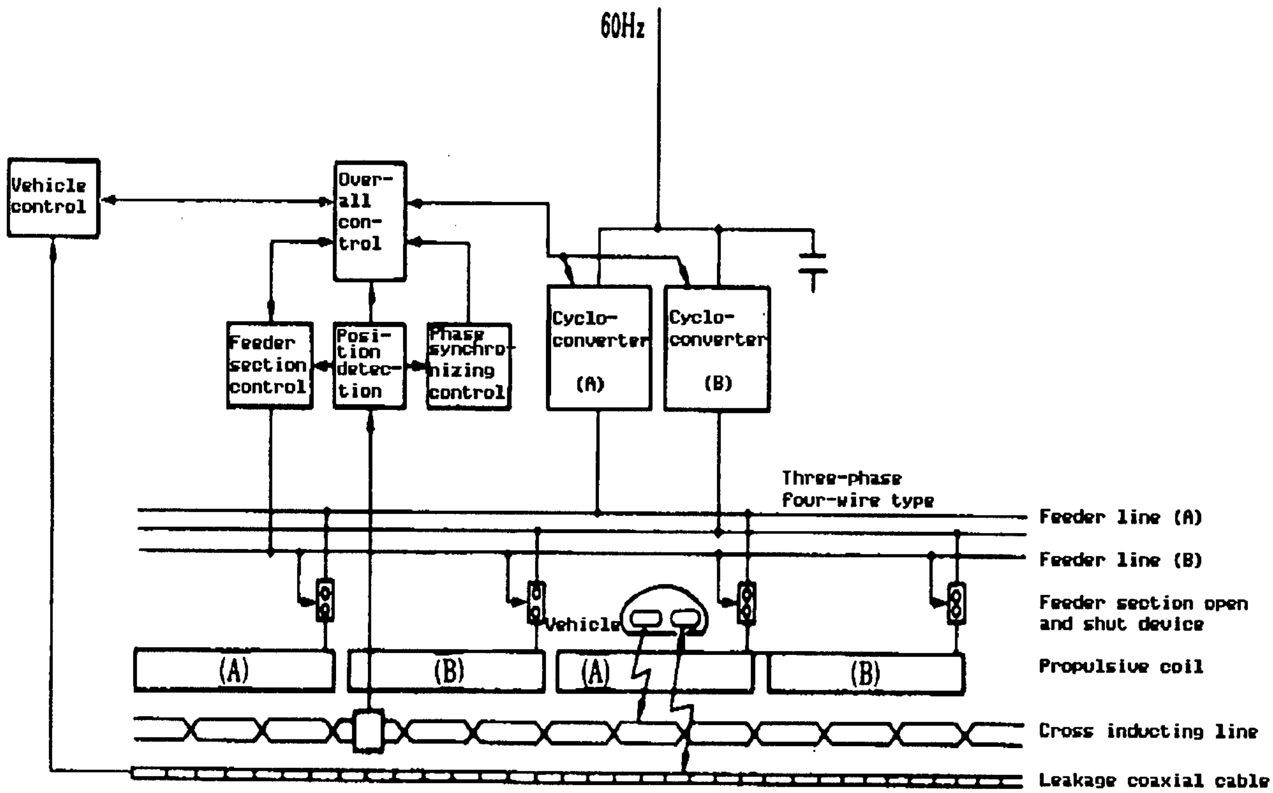


Figure 3. Electric Power Supply System of Miyazaki Experimental Line

Table 1 lists the main specifications of MLU 002, and its configuration is shown in Figure 4. MLU 002 has a length of 22 m, about twice that of MLU 001, and almost the same as that of a commercial vehicle. In the case of MLU 001, superconducting magnets are consecutively arranged in the direction of the vehicle. On the other hand, the number of magnets used in MLU 002 has been reduced, reflecting higher performances of the superconducting magnets. In a standard train of an ordinary railroad, the magnets are concentrated in the chassis. A reduction in the number of superconducting magnets is useful for reducing the weight of the whole vehicle, an improvement in the mass ratio of a body to a chassis which contributes to riding comfort and cost reduction.

Since only one MLU 002 is going to be built, both ends are round. This train can seat only 44 people, since measurement equipment is also placed on the floor. However, the commercial form of this train will have a capacity of approximately 70 to 80 people. Due to the fact that this vehicle must run on the experimental line, traveling a total distance of only 7 km in order to ensure a safe braking distance, and also since high acceleration as experienced in the unmanned ML 500 should be avoided, its maximum running speed will be only 420 km/h. Of course, the maximum speed of the commercial form will become 500 km/h.

Table 1. Main Specifications of MLU 002

Vehicle dimensions: length x width x height	22.0 m x 3.0 m x 3.7 m
Seating capacity	44 persons
Weight	17 tons
Superconducting coils	
Number	3-poles x 2-chassis x 2-rows
Magnetic generation power	700 kA
Polar pitch	2,100 mm
Floating	
Floating power	196 kN
Effective pitch	110 mm
Guide	
Guide force	83.3 kN (at 50 mm disp.)
Effective pitch	150 mm or more
Propulsive force	0 to 79.4 kN
Number of phases	3
Frequency	0 to 28 Hz
Voltage	5,800 V
Electric current	900 A
Maximum speed	420 km/h

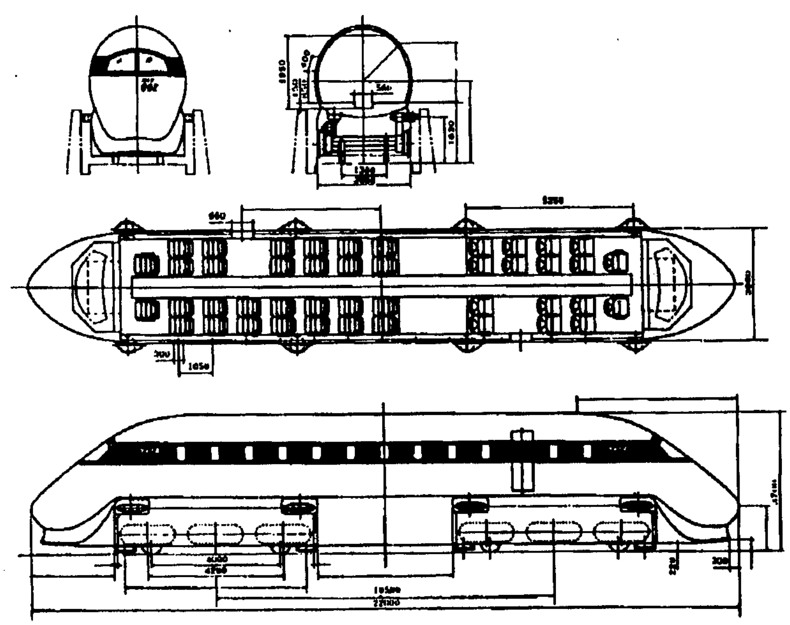


Figure 4. MLU Experimental Vehicle

(2) Superconducting magnet

With the development of MLU 001, superconducting magnets used for a lightweight, compact vehicle experiencing no thermal invasion and integrated with a freezer, have almost been developed. Their high reliability has also been verified. There are two types of magnets used for MLU 001: one is the two-coil type (two superconducting coils are used), and the other is the one-coil type, which is the largest one, is applied. In addition, the following developmental results have been incorporated into this vehicle.

Niobium-titanium alloy wire material is employed for the superconducting coil. The ratio of the cross-sectional area of copper to the superconducting material has been reduced from 2 to 1, further decreasing its weight. In addition, its exciting degaussing performance has been improved, whereby exciting degaussing can be accomplished within 1 minute. The operational time at the base has, therefore, been drastically cut and thermal invasion from the outside through the power lead has also been reduced. It can be said that the realization of superconducting magnets which do not rely on the ground base, which is planned for commercial operation, is much closer.

As for the freezer to be installed in a vehicle, not only the closed cycle system, but also the Stirling cycle freezer combined with a Joule-Thomson (JT) loop have been used for MLU 001. On the other hand, reflecting the results of the consignment study "Research and Development of Small High Performance Freezers" conducted by the Science and Technology Agency, a complete Stirling cycle freezer without JT will be used first in the MLU 002. This freezer is assembled into one chassis, and a closed cycle freezer is put into the other one. A comparison is going to be made. Since the Stirling cycle is highly efficient and requires no valve mechanism, it gains maintenance advantage.

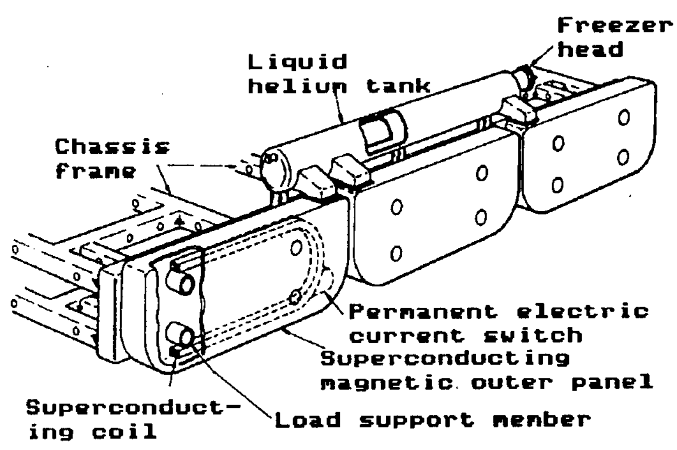


Figure 5. Superconducting Magnet for Prototype Vehicle

(3) Body and platform car

MLU 001 was manufactured mainly for use in the magnetic floating experiment. However, in the MLU 002, in order to reduce the air resistance, aerodynamic instability and aerodynamic noise, various means, including the application of

optimal shape through wind tunnel tests, smooth and flat surfaces (eliminating the difference in levels at windows, changing from riveting connections to welding, etc.), complete housing of supplementary supporting wheels during floating, a cover attached to supplementary guide wheels, airtight body structure, etc. are incorporated. The center portion of the body is made using an aluminum alloy, but the front portion is made with DFRP. Air springs, dampers, and anchors are placed between a body and a chassis. At the four corners of each chassis, an emergency landing device (gliding shoe) is provided in case of the puncture of a supplemental supporting wheel. This device also works as a mechanical brake which rubs guideways when abnormalities occur to the electric brake.

Regarding cabin facilities, not only illumination and air conditioning, but also an information panel for cabin guidance have been installed. Due to the substantial deceleration, seat belts have also been provided. Judging from the past experimental results, electricity of about 50 kw (commercial base) is necessary for one vehicle, including a freezer power unit, which will be prepared by an on contact-type collector when the speed reaches at least 160 km/h. Since the Miyazaki experimental line is so short, there is not enough time to collect enough electricity. Therefore, MLU 002 will rely on batteries as in the past.

4. Circulated Electric Current-Type Cycloconverter

An alternating current of variable amplitude and variable frequency passing through a propulsive guide coil is supplied by a cycloconverter installed in a substation. In the case of the Miyazaki experimental line, its frequency is 0 to 34 Hz, corresponding to the vehicular speed of 0 to 500 km/h. Because the output frequency of a conventional cycloconverter is about one-third the input frequency at the maximum, a three-phase current of 60 Hz is converted into a current of 120 Hz by a motor generator (MG), and then supplied to the cycloconverter. The MG method has the advantage of absorbing high-frequency and reactive electric power. However, its system is too large, e.g., its total mass is 140 tons when the motor is working at 10 MW and the generator at 25 MVA. There is also difficulty in maintenance. The newly-constructed electric power supply system is called a circulated electric current-type cycloconverter. Since the output frequency can be increased up to two-thirds of the input frequency, it can receive electricity directly, without the aid of an MG (Figure 6).

The composition of the circulated electric current-type cycloconverter is shown in Figure 7. Two pairs of converts for each phase are arranged in an inverse parallel circuit by a reactor for ripple current control, and the middle point of this reactor is connected to the LSM load. The two pairs of converters are insulated by an input transformer. Each converter is composed of 24 pulse converters, which are connected to a 4-stage cascade by 6 pulse converters. A condenser is connected at the input side of the cycloconverter through a thyristor switch.

The pattern of an electric current which passes through a propulsive guide coil is given to the control portion. In order for an output electric current to be an ondogram, as specified by this pattern, the generated voltage of the

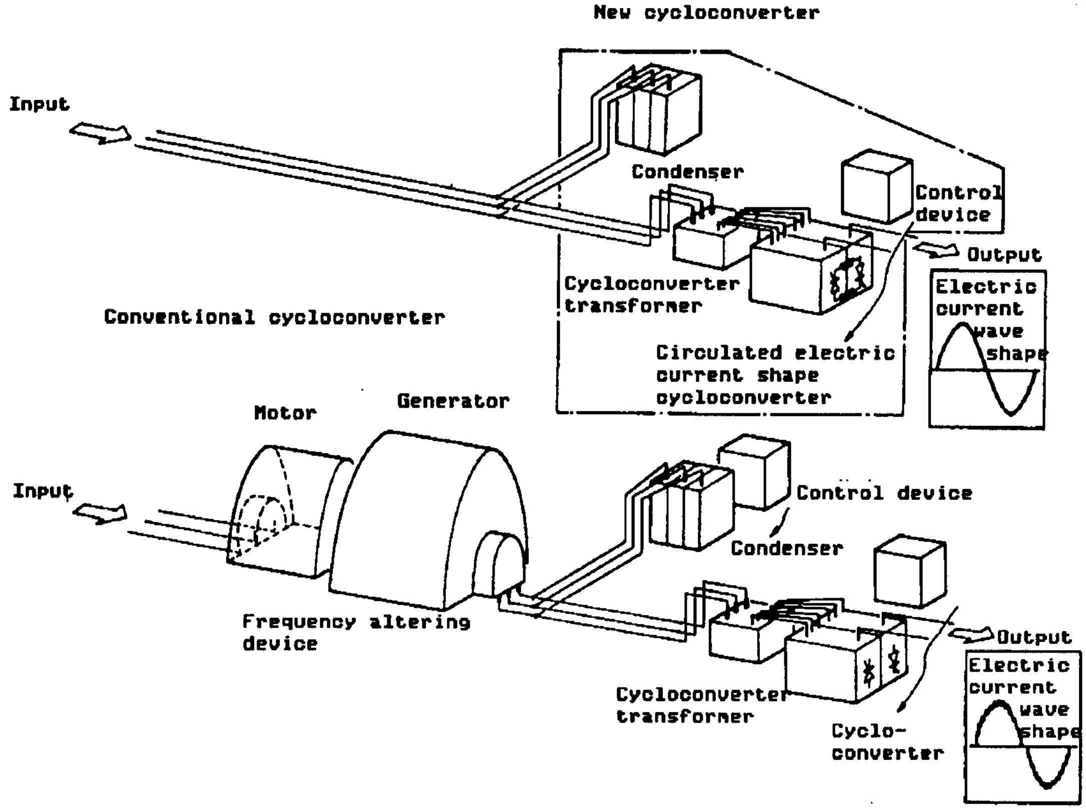


Figure 6. Comparison of New and Old Cycloconverter

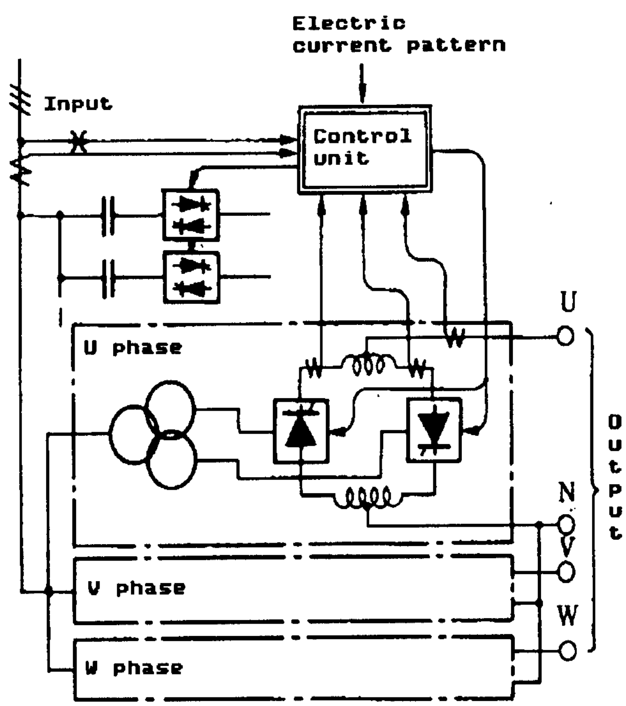


Figure 7. Composition of Circulated Electric Current-Type Cycloconverter

two pairs of converters is controlled. At the control portion, a thyristor switch turns on or off in accordance with the magnitude of the output current, and condensers needed to get the necessary capacity are connected to the input side. In addition, the circulated currents which pass through both the converters are adjusted and controlled so that advanced phase reactive electricity, generated by the condensers, and delayed phase reactive electricity, created by the cycloconverters, cancel each other, resulting in the synthetic reactive electricity of zero. Condensers with large capacities and filters are needed as countermeasures for reactive electricity and high frequency, respectively. In the case of the conventional noncirculated electric current system, a sine wave has not been obtained due to the necessity of electric current resting time. On the other hand, a better wave shape can be obtained using the circulated electric current system.

The conventional electric source facility corresponds to the ML 500 experimental vehicle. Its capacity is only 10 MVA (since the experimental line is short, and it is necessary to get high acceleration, this figure is larger than that of a commercial line). When MLU 001 was connected, the maximum speed became 350 km/h for two carriages and 222 km/h for three carriages. The capacity of the new cycloconverter was increased to 16 MVA, resulting in the maximum speed of 352 km/h recorded for a three-carriage vehicle in December 1986. An experiment involving a speed of 400 km/h is scheduled to be conducted for a two-carriage vehicle.

5. Future Plans

MLU 002 will be completed by the end of March 1987, followed by full-scale tests scheduled to begin in April. At this moment it is estimated that it may take 2 years to complete the tests. However, final confirmation could be given within 1 year. Due to the preconception that superconducting systems require large-scale facilities, this system has been rejected only for long distance sections, such as between Tokyo and Osaka. However, from the results of repeated tests on the 7 km Miyazaki experimental line, the idea to use the system for short distance application has been accepted. Although no changes have been made to the basic system, future plans will distinguish between short and long distances.

(1) Short distance application

For the ground-first-type LSM, the train and substation correspond. Therefore, if a shuttle operation takes place within a section of this length, only one substation is needed. Since junctions at both end stations are initiated by wheel action, it is possible to use a simple junction device, already being applied, for a new transportation line using rubber tires. If a five- to six-carriage train is being operated, the ground coils of the 6,000 to 7,000 V class, which are used for the Miyazaki experimental line, are applicable, i.e., for a short distance, the substation's junction devices and ground coils, at the present technological level, can be utilized. After final confirmation by MLU 002, construction work for a short distance system, such as airport access, could be possible as soon as 1988.

(2) Long-distance application

Several developments are planned for the future. They include a method to control a vehicle which passes through the borderline between substations placed at regular distances of 50 km, a high-speed branching device located at a station through which a vehicle can pass at its maximum speed, and a high pressure-resistant ground coil necessary for the operation of a vehicle with a large number of carriages. Regarding these items, simulation, theoretical examination, and basic magnetic experiments are presently taking place. Although major problems have been encountered, it may take 2 to 3 years for their completion.

In the case of a long-distance line, as seen from the past model lines, i.e., the Kamonomiya section in the New Tokaido line and the Oyama section in the New Tohoku line, the model line of a distance of 40 to 50 km is constructed first. Then, synthetic evaluation, such as the situation in which trains pass each other and a train passes through a tunnel, is necessary. It is possible to proceed in the development of the items described above and the construction of the model line at the same time.

6. Conclusion

The superconducting magnetic floating type railroad developed by JR is presently internationally unique. Canada has also started developing a superconducting coil, in order to obtain a similar system which would be able to resist snow. Since the technology of this superconducting system has not yet been proven, some people think that a concrete construction plan for this system will have to wait until the future. Therefore, in order to get people to understand the progress made on its development, a demonstration of MLU 002 is thought to be very important.

In Japan, the development of a superconducting electromagnetic thrust ship having no screws has just been started. In addition, plans for a Japanese-space shuttle launched by a multiple-stage rocket with the aid of a magnetic floating-type sled, and a magnetic floating train with a vacuum tube system which would pass through a sealed tunnel between continents may be no longer a dream.

The development of the floating-type railroad is being carried out by the Railroad Synthetic Technical Institute newly organized in April 1987. I am deeply grateful to the Ministry of Transport, universities, production workers, and related people for their help and cooperation. At the same time, their continuous support is very much appreciated.

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